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ABSTRACT

This manual is intended as a reference. Teachers who use it should select the materials best suited to their work. The first part of the manual is devoted to the sense of sight, for that is of fundamental importance in understanding why certain practices are recommended. The next section presents the principles of light control and of lighting for eye comfort and contains applications of the principles of correct lighting in home and school. The third section makes suggestions to teachers about advantageously introducing material on sight conservation and lighting. It also suggests some activities and experiments that may be useful in presenting these materials to the pupils. The fourth section lists sources of further information: books, pamphlets, periodicals, and agencies supplying information and materials. (Author/CP)

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Teaching About

Light and Sight

National Education Association

PREFACE

This handbook is designed to help classroom teachers in elementary and secondary schools to teach about light and sight in order to safeguard and conserve the eyes.

Schools should take precautions to safeguard the eyes from injury and to provide conditions for easy seeing; they should employ health procedures to aid in the early discovery and correction of vision defects; and they should provide instruction in good habits of using and caring for the eyes.

It is not advocated here that a separate course be given to cover the materials in this manual, but rather that all teachers help to meet the problem. Classroom teachers can insist on good study habits and can emphasize those parts of the curriculum that contribute to an understanding of the eyes and their proper care and use.

This manual is intended as a reference. Teachers who use it should select the materials best suited to their work. The first part of the manual is devoted to the sense of sight, for that is of fundamental importance in understanding why certain practices are recommended. The next section presents the principles of light control and of lighting for eye comfort and contains applications of the principles of correct lighting in home and school. The third section makes suggestions to teachers about where they may advantageously introduce material on sight conservation and lighting. It also suggests some activities and experiments that may be useful in presenting these materials to the pupils. The fourth section lists sources of further information—books, pamphlets, periodicals, and agencies supplying information and materials.

Although much of the material in this manual should be simplified for presentation to elementary-school pupils, teachers may find the more difficult material helpful as a background for their work. They will also find activities that can readily be used with younger pupils.

High-school teachers whose work is confined to one or two areas in the curriculum may prefer to examine the suggestions for teaching and then read the parts that contribute information to the subject fields for which they are responsible.

Classroom teachers, principals, and supervisors alike may find helpful suggestions in the part on school lighting. Those who must construct programs for the school and those responsible for school health measures will find pertinent material in all of the sections. Those who participate actively in the planning of new buildings or the remodeling of old ones should know the minimum desirable specifications for the lighting of classrooms and other parts of the school plant. All teachers should know what constitutes good classroom lighting both to compensate as fully as possible for existing deficiencies and to avoid practices that might nullify good conditions.

Students, too, have found past editions of this handbook useful for reference. The new, more attractive and readable format of this edition should enhance its direct usefulness for students.

The NEA Research Division wrote the earlier editions of the handbook. This fourth edition has been prepared by the NEA Publications Division. The Division is particularly indebted to the following persons, but, of course, assumes responsibility for its own errors or inadequacies: Philip M. Alden, chairman, Better Light Better Sight Bureau; Dr. Henry Bastien, chairman, Ophthalmology Section, District of Columbia Medical Society; Edward A. Campbell, manager, Better Light Better Sight Bureau; C. L. Crouch, technical director, Illuminating Engineering Society; and Frank W. Hubbard, assistant executive secretary for information services, NEA.

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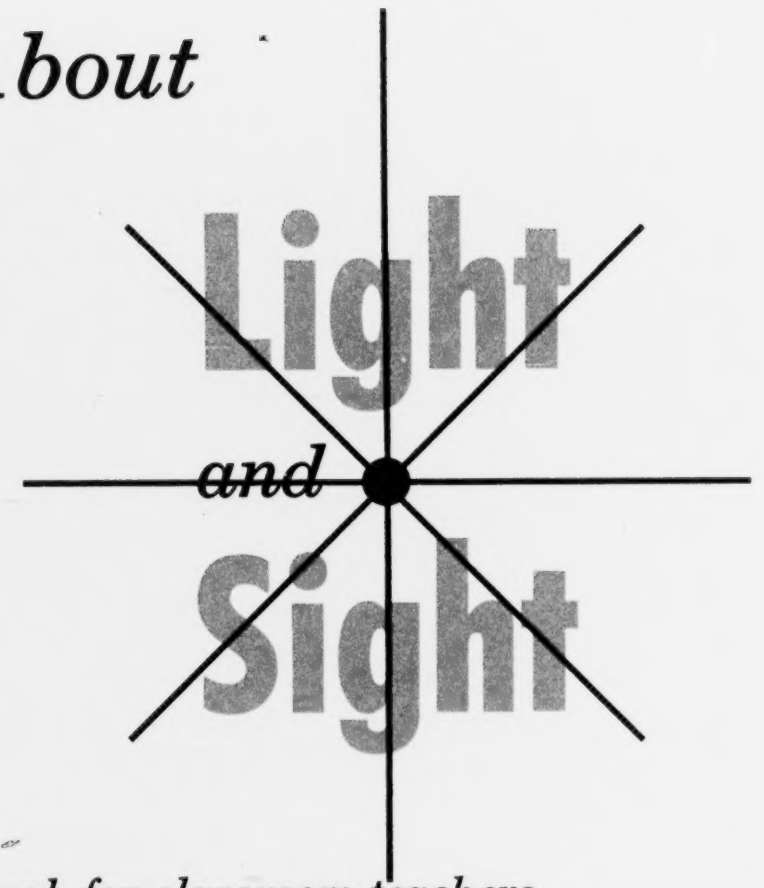
NEA Publications Division

Teaching About



A handbook for classroom teachers
in elementary and secondary schools

National Education Association
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SIGHT

FIG. 1 Cross Section of the Human Eye

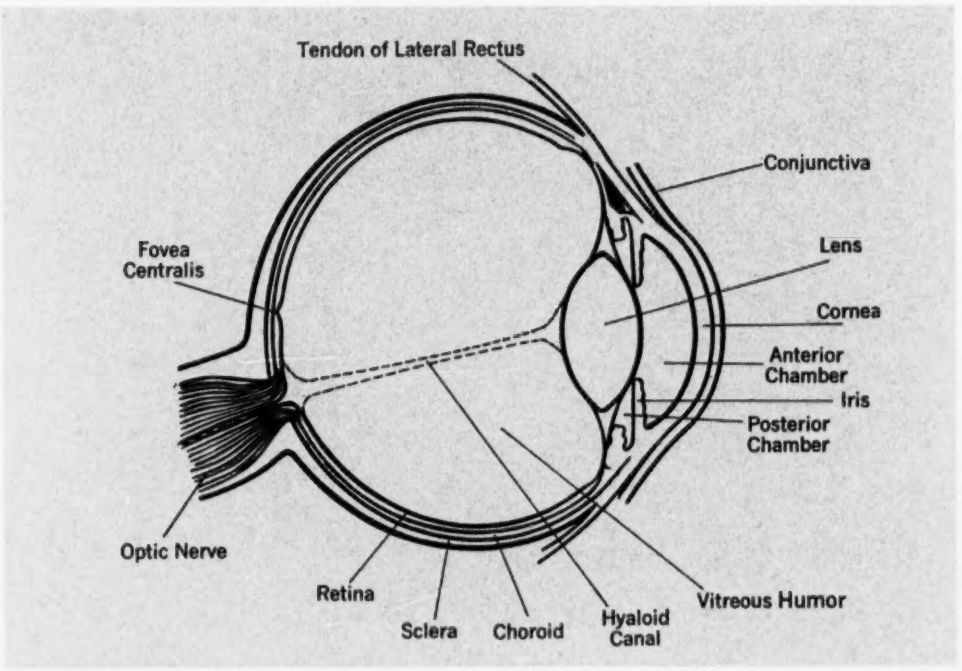
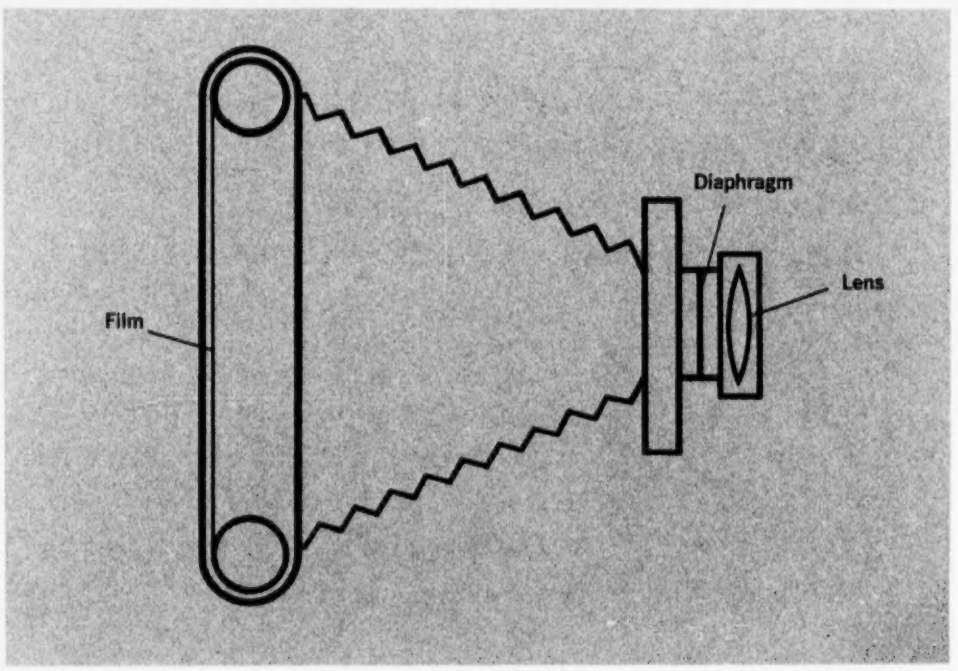


FIG. 2 . . . Compared to a Camera



Sight is a reaction to light. Among living creatures, there are varying degrees of dependence upon sight, as opposed to the other senses. Man is one of those to whom sight is of great importance.

Although living creatures have many kinds of eyes, usually adapted to the needs of the environment, most vertebrates have eyes much like man's. Curiously, however, the animal with eyes most like ours is the octopus.

Many animals' eyes have "extra added attractions," such as the nictitating membrane, a kind of third eyelid which slides over the eye from the side nearest the nose. Some have an extra membrance behind the retina of the eye; it is this membrane, acting as a mirror reflecting light back to the retina, that causes a cat's eyes to shine in direct light.

Some other differences between our eye structure and those of other animals are traceable to different needs. For example, whereas the pupils of our eyes are round, cats' pupils are vertical slits, more satisfactory for providing up-and-down vision, and horses' pupils are horizontal slits, helpful in side-to-side vision.

Fish and animals active in the dark tend to have extra-large eyes; the eagle, which depends heavily on its keen sight, has a larger eye than man. On the other hand, creatures that live in complete darkness, such as cave animals and fish found at great depths in the ocean, are usually blind, and their eyes are relatively small.

THE NORMAL HUMAN EYE

Perhaps the quickest way to understand the basic structure of the human eye is to compare it to a camera. (See Figs. 1 and 2.) The iris of the eye is a self-adjusting diaphragm with an opening, the pupil, which admits light. This is similar to the diaphragm and shutter in a camera. Light rays pass through the lens of the eye as of a camera and are focused on the retina, which corresponds to the film used in a camera. The interior of the eye, like that of a camera, is dark.

Although this is a helpful and reasonably accurate analogy, it is also an oversimplification. Actually, the eye is a very intricate structure. There are a number of yet unanswered questions about its basic physiological processes, particularly those concerning the functions of the retina and the working relationship between the eye and the brain.

The human eye rests in a protective bony cavity and is further supported by fatty tissue which acts as a shock absorber. The eyelids, eyelashes, and eyebrows also afford protection, from perspiration and dust and from the brilliance of the sun. The eyelids not only shut out light to permit sleep, but also close instantly over the eye at any hint of danger to it.

The surface of the eyeball is kept moist and smooth by the secretions of the tear glands. These tears are carried away through the nose by tiny ducts. Although the tears are always present, we notice them only when they are so profuse that their volume is too great for the ducts, as when we cry, or when the nasal passages are blocked, as when we are affected by colds or allergies.

Surrounding the globular eyeball are three pairs of extrinsic muscles, which allow us to see in different directions without moving our heads. These muscles also enable the eyes to focus together on the same point in the field of vision; this ability, necessary in order to receive a clear impression of depth, is called binocular vision. It is not present at birth, but is developed during the first six years of life.

Since, normally, we look at an object with both eyes simultaneously, the field of vision of each eye overlaps the other. Although the total visual field of both eyes combined is larger than the visual field of either eye alone, a portion of the field of each eye is blocked off by the nose, eyebrow, and cheek. The remaining joint field of vision, or binocular field, has a radius of about 60 degrees.

What Is It Made Of?

The outer covering of the eyeball is the sclera, a tough opaque membrane. The forward portion of the sclera is the cornea, which protrudes slightly; the cornea is transparent and is the first point at which light rays enter the eye. The choroid, a deeply

colored layer composed largely of blood vessels and connective tissue, lies just behind the sclera.

The aqueous humor, a colorless liquid secreted by the ciliary body behind the cornea, fills the space in the front of the eye between the cornea and the lens. It is the second substance through which light rays pass. The iris, the opaque membrane that gives the eye its distinctive color, is suspended in the aqueous humor. At the center of the iris is the pupil, seen from the outside as a black circle. In actuality, the pupil is an opening whose darkness is simply a view of the darkness of the inner eye.

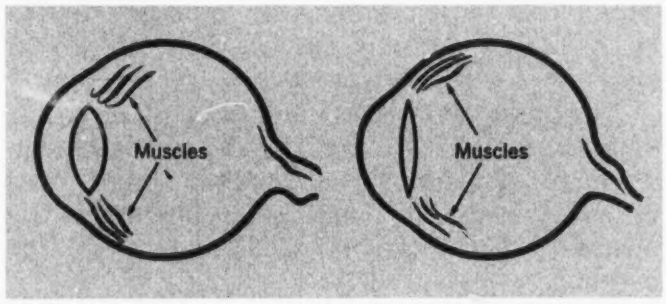
Ophthalmologists—doctors who specialize in the treatment of our eyes—frequently make use of eye drops containing a drug that dilates the pupils; thus, they are able to examine, through the widened aperture, the parts of the eye behind the iris. After such an examination, unless we wear dark glasses for a little while, we experience a certain degree of mild discomfort because the temporary interference with the normal regulation of the size of the pupil results in the admission of too much light to the lens. As the drug wears off, the muscles located in the iris reassume command, and the pupil is once again automatically adapted to changes in the degree of light: without our being aware of it, the aperture is narrowed in the presence of bright light; in the dark, it is expanded.

After light passes through the pupil, it reaches the lens, situated just behind the pupil. The lens, which grows in size as we grow, serves to focus the rays of light on the retina.

Since light rays reaching the eye from a distant object are almost parallel and those from a near object are spread out, a lens of unvarying thickness could not focus both kinds of rays on the retina at the same time without distortion of the image. This difficult problem is overcome by the process of accommodation, wherein the shape of the lens is altered by tiny muscles to adjust to the eye's distance from the object. (See Fig. 3.)

The last substance through which light rays pass before reaching the retina is the vitreous humor, a jellylike material occupying the cavity of the globe behind the lens. The vitreous humor, like the lens, must be clear and transparent for good vision.

FIG. 3 Accommodation



The retina, a soft transparent membrane of paperlike thinness, contains the nerve-end structures, or photoreceptors, which are truly at the center of the act of seeing. These are of two types, named for their appearance under the microscope: the rods, which are cylindrical, and the cones, which are flask-shaped. There are about 125 million rods in each eye and about 7 million cones. The fovea centralis, a small depression in the retina in line with the pupil, is closely packed with cones, but contains no rods. The fovea is the area of greatest visual acuity for each eye.

How Does It Work?

In general, the proportion of cones increases in the center of the retina, and the proportion of rods increases at the outer edges. The cones, which are sensitive to good illumination, are thought to be responsible for seeing colors; the rods, which are sensitive to small amounts of light, are largely responsible for night vision. The rods produce the visual purple, a pigment that undergoes chemical changes when absorbing light. When light reaches the retina, these chemical changes cause electrical impulses to pass along the nerve fibers to the optic nerve and on to the brain.

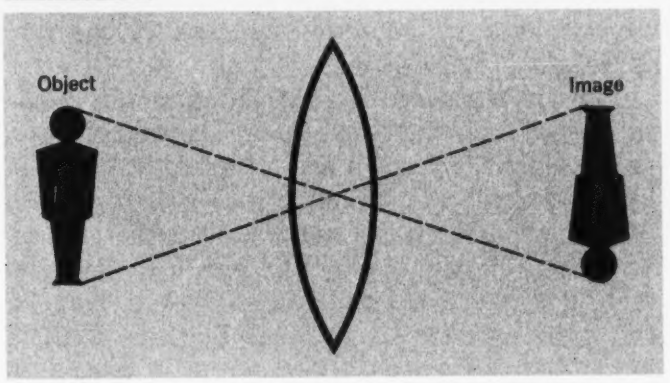
The cones have individual fibers to carry the impulses to the brain, whereas several rods are connected to each fiber. It is thought that this is why peripheral images—those seen with the rods—are not sharp or distinct.

The complex system of optic nerve fibers is gathered together at the back of the eye to form the optic nerve. The two optic nerves meet behind the eyes, where each set of

fibers leads to its own side of the brain. In addition to the optic tract, more than half of all the cranial nerves contribute to the act of seeing.

The final step in the process of seeing is performed by the brain. As the illustration shows (see Fig. 4), when light rays given off by the object to be seen are finally focused on the retina, the image is upside down. Without our being conscious of it, the brain simply inverts the image, so that at the moment we are aware of seeing it, the picture is right side up.

FIG. 4 Image Inversion



The object seen is upside down on the retina because the light rays are bent on their way to the retina. Although light rays tend to travel in a straight line, they are bent when they pass from one substance to another of a different density. This bending, or refraction, occurs several times between the cornea and the retina, as the substances through which light passes after it enters the eye are of varied density, ranging from liquid to solid. All of them are different from the original substance (air). As a result, the rays forming the top of the object seen become the bottom of the image on the retina, and vice versa.

The refraction of light rays causes the same inversion of the image when we focus a camera; in modern and complex cameras, mirrors or prisms perform the job that the brain does for the eye. They turn the image right side up again, so that we may see the picture as it will finally appear. Cameras without this mechanical aid, such as some studio cameras, show the photographer the image upside down.

Do It Yourself

Most of us will never see for ourselves the complex mechanism of the eye in operation; some parts of the system, such as the rods and cones, cannot be seen without a microscope in any case. But we can demonstrate the effects of what we have learned about the construction and functions of the eye by means of simple experiments.

For example, a distinction between some of the functions of the rods and the cones can be seen on any starry night. If you look directly at a star, you will find that it looks less bright than it does if you look slightly to the side of it. This is because the cones, concentrated at the center of vision, are relatively insensitive in dim light. By looking a little to one side, you cause the image to fall on the rods, which can operate in the dimmest illumination in which man is capable of seeing.

Here is another experiment: You may have heard of the "blind spot," which sometimes is blamed by ball players who fail to make a catch. It is true that in one spot in the retina, at the point where the optic nerves gather at the back of the eye to form the optic nerve, there are neither rods nor cones; without these photoreceptors, there is no vision. Usually, we do not notice this tiny spot, but each of us can locate it for himself by means of this simple experiment:

Place two dots about five inches apart on a piece of paper. Hold the paper about 12 inches from your face. Close your left eye and look steadily at the left-hand dot. While watching the left-hand dot, move the paper first slowly away from and then back toward your face. The right-hand dot, which you have not been looking at but which has still been in your field of vision, will disappear from your view when its image falls on your blind spot.

DEFECTIVE SI[illegible]T

Most studies indicate that 20 to 30 percent of elementary-school children have significant eye defects. While the detection and correction of such defects are the direct

responsibilities of parents and their medical advisers, a knowledge of the causes and effects of defects in sight should be helpful to all teachers. In this section, common eye defects and their causes are described. Typical behavior indicating the possible presence of visual difficulty is listed in the next section. Classroom teachers should look for these signs and call them to the attention of parents. It is important, however, for teachers to remember that, even in cases where children's sight is being corrected by glasses or other means, the eyes may lack the adaptability of fully normal eyes.

Any deviation from the theoretically normal eye in structure and function is, in a sense, a defect of sight. For practical purposes, however, the term "defective sight" usually is applied only to those deviations which are great enough to interfere with efficiency or comfort.

Although the mechanism involved in the seeing process is complex, the normal eye is, on the whole, adaptable and efficient. Why, then, do so many people nowadays need to wear eyeglasses?

Two possible answers are those that explain many other recent alterations in the national health picture: we have more older people, and our people have more education and more money. Many elements of the seeing mechanism change with advancing years: the lens, for example, begins to become less able to accommodate as early as age 40. Not only do we have more people of 40 and 50 alive today than we used to have but also they are active, often in mid-career, and thus more likely to notice the need for and to demand help with their vision than were the middle-aged of a generation ago.

The combined rise in the educational level and material standard of living in our country has resulted in better methods of diagnosis and treatment of vision difficulties, along with a more widespread awareness of the possibility of aid and an improved ability to pay for it; the medical profession and the public tend to interact in this matter, with better methods encouraging people to seek treatment and increasing numbers of patients spurring the development of better methods.

Possibly the change from a chiefly rural to a chiefly urban society may also explain the wider use of eyeglasses. Today's workaday world is largely a paperwork one; people active in it are distressed or ever hampered if they lack visual acuity. Many of our tasks are more detailed and more lacking in variety than those our forebears performed; to an ever-increasing degree, our tasks are performed in conditions of artificial, rather than natural, illumination. In this changed picture, eye defects that once passed unnoticed are brought to attention.

Common Eye Defects

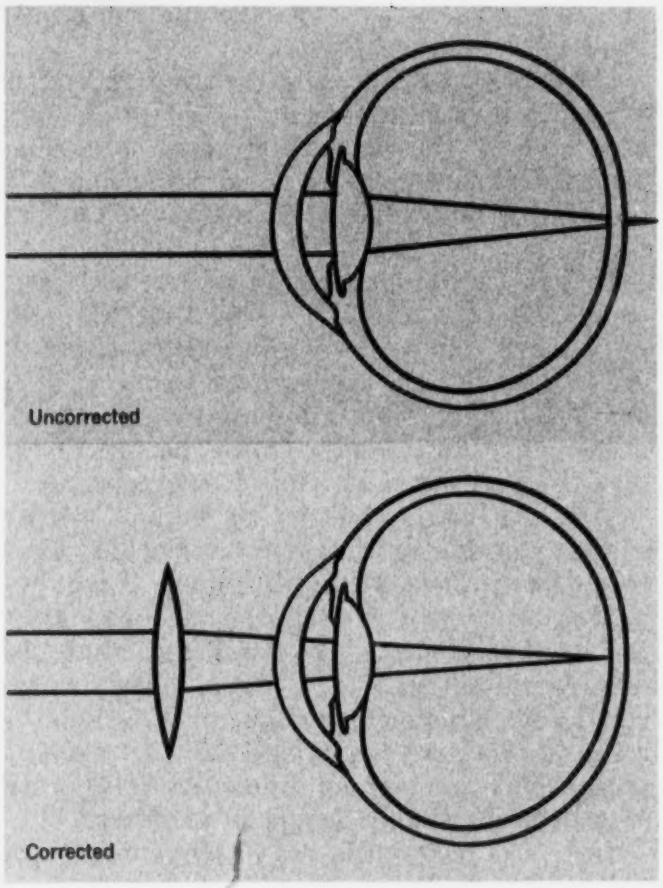
FARSIGHTEDNESS is characterized by difficulty in seeing nearby objects, although the individual is able to see well enough generally and is usually uncomfortable only when constantly occupied in close work, such as reading or sewing.

The explanation of farsightedness is indicated by its scientific name, hypermetropia (also called hyperopia). Hypermetropia is derived from the Greek words *hyper,* which means "excessive"; *metron,* which means "measure"; and *opos,* "the eye." In this defect, the eye measures excessively; that is, the distance required within the eye for the light rays to reach their point of focus is excessive, either because the eyeball itself is too short or because the rays are spread apart as they pass through a defectively curved lens or cornea. When the farsighted person looks at a near object, the light rays have not yet focused by the time they reach the retina; so the only image that could appear on the retina would look like an out-of-focus photograph. To avoid this, the lens accommodates, just as it does when the normal eye needs to see at a distance. Thus, the power of accommodation is required to be in use much of the time in a farsighted person's eyes.

Most children are slightly farsighted, but their power of accommodation is so strong that they are not troubled by the condition. As they grow older, the farsightedness decreases and their sight usually becomes normal. Correction is unnecessary unless the defect is extreme or the child shows signs of eyestrain.

Farsightedness can be corrected by the use of glasses with convex lenses. A convex lens, thicker in the middle than at the edges, bends the light rays toward each other as they pass through it, thus shortening the

FIG. 5 Farsighted Eye



distance to the focal point. The image can then be focused clearly on the retina, and, since the eye's own accommodation mechanism no longer needs to do this job alone, eyestrain is reduced. (See Fig. 5.)

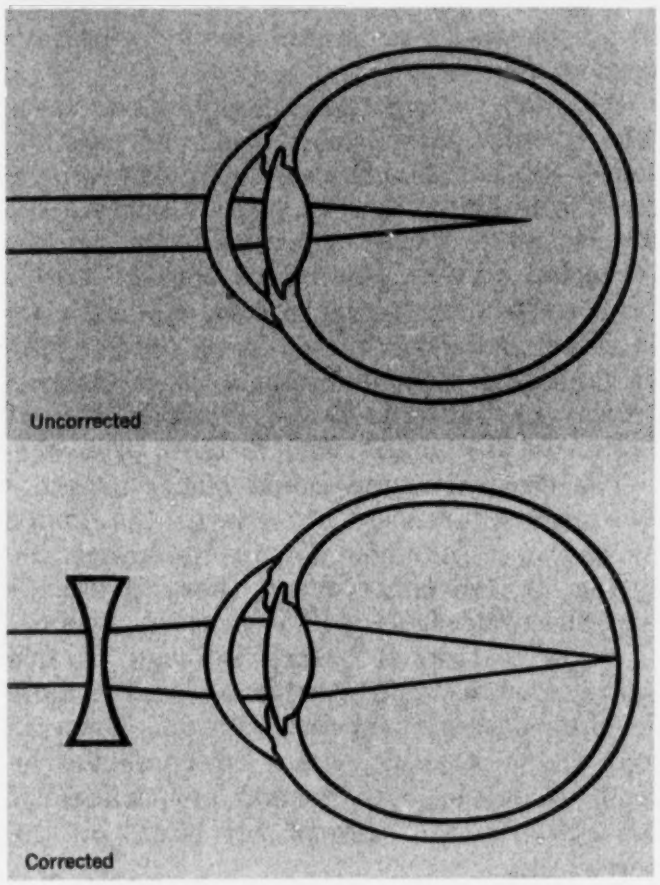
PRESBYOPIA, sometimes called "old-sightedness," is a characteristic eye difficulty of middle age. Distance vision remains clear but, with the gradual failure of the power of accommodation, the individual is unable to focus on nearby objects without the aid of convex lenses. This condition, however, should not be confused with farsightedness.

NEARSIGHTEDNESS (myopia) is a condition of the eye in which light rays from a distant object come to a focus before they reach the retina. The defect may be due to a long eyeball, so that the rays must travel too far before reaching the retina, or to too much curvature of the lens or the cornea, so that rays are bent more sharply than usual and therefore focus earlier than they should for a clear image.

People who have myopia see near objects well enough; since the image on the retina cannot be made clearer by the power of accommodation, as in farsightedness, they do not suffer from strain caused by constant adjustment, as the farsighted frequently do. Unless their work demands seeing at a distance, nearsighted people often give up trying to see anything far away; if they are not with others who habitually see clearly what is a blur to them, they may not even suspect that anything is wrong.

Myopic children who are fitted with glasses usually show considerable surprise and pleasure at their first clear view of objects that have been beyond their range of vision all their lives. In the classroom, myopic children who are otherwise alert and interested will usually be noticed because they come forward to peer closely at whatever is being exhibited and, unless they are hampered by lack of confidence or by other psychological problems, often ask to have their places changed or complain to the teacher that they cannot see. Others may simply withdraw and make no effort; in these cases, experienced teachers usually sus-

FIG. 6 Nearsighted Eye



pect visual difficulties among the first possibilities when considering the child's problems. This defect is also quite often detected by school eye-testing programs.

Myopia tends to increase during the growth years, but it usually becomes stabilized in adult years. There is, however, a more severe form of myopia which progresses rapidly and may result in serious difficulties; it was for children with this affliction that the first sight-saving classes were begun.

Ordinary myopia is corrected by glasses with concave lenses. The concave lens, thinner in the center than at the edges, spreads the light rays apart as they pass through it. Thus the rays are prevented from reaching a focal point before they reach the retina. (See Fig. 6 on p. 9.) The more severe form of myopia requires, in addition to glasses, special attention to general health and, usually, special educational adjustments to conserve the sight.

ASTIGMATISM is the blurring of parts of an otherwise normal image on the retina because of an irregularity of the lens or cornea, which causes some rays of light to focus farsightedly or nearsightedly. People who have astigmatism sometimes tilt their heads to one side in an effort to achieve clearer vision.

Although there are complicated cases where only partial correction is possible, lenses ground in such a way as to compensate for the irregularity will usually correct the defect. Some cases of astigmatism can be corrected only by the use of contact lenses.

CROSSED EYES (strabismus), the inability to direct both eyes to the same object, may be caused by muscular imbalance, nearsightedness or farsightedness, weak power of fusion, or any combination of these problems.

The cross-eyed individual either uses the two eyes alternately or ignores the image in one eye and depends on the other for seeing. In the latter event, there is danger that the unused eye will lose useful vision.

If he is treated before the age of five years, a child with strabismus will usually develop normal binocular vision. Even if that is not possible, every effort should be made to restore the normal appearance of the eyes for the sake of the effect on the personality.

Depending on the cause and severity of the defect, surgery, orthoptics (eye exercises), glasses, or any combination of the three may be prescribed.

COLOR BLINDNESS. Although not too much is known about how color is seen when light rays reach the human retina, it seems probable that the cones are differentiated in some way and react differently to various colors.

In our earlier discussion of the rods and the cones (see p. 6), we said that the rods were more concentrated toward the edges of the retina and the cones were grouped near the center of it. The following simple experiment helps us to demonstrate the conclusion that color vision is the job of the cones:

Mix up small squares of colored paper so that you don't remember their order. Then focus your eyes straight ahead. Take one square and move it around your head from the back to the side. You will find that you will catch sight of the paper long before you know which color it is, as soon as the rods in your eye respond to the moving paper. But you cannot know its color until it is brought within range of the cones.

In total color blindness, which is extremely rare, all colors are seen as gray; this is thought to be a lack of cone function and, unlike the more common forms of color blindness, affects male and female about equally. Partial color blindness, which is the type commonly found, is believed to be inherited through the male line; that is, although women may carry the trait, usually they merely pass it on to their male children without becoming color-blind themselves. Four out of 100 men have this visual defect in whole or in part, but only one out of 200 women have it. Dogs and many other animals are color-blind.

The most common types of color blindness are red blindness, where the colors at the red end of the spectrum seem to be gray, and red-green blindness, where both blue-greens and red-purples are seen as grays. Both types can see blues and yellows.

Many children with color blindness adjust to their defect, so that it goes unnoticed: where others distinguish an object first by its color, they learn to identify it by some other characteristic. When the class visits the local firehouse, for example, the outstanding feature of the fire engine to the color-blind

child is its bell or its ladders, rather than its distinctive red color. Often, unless children's color vision is specifically tested, they can remain unaware of their defect into adulthood.

Since those who suffer from color blindness can distinguish brightness even where they cannot distinguish colors, they are not especially handicapped in everyday matters like observing traffic lights; although both red and green lights look gray to them, they know the relative positions of the lights, and they can tell which one is lighted by the degree of brightness. They may not be eligible for employment, however, in some industries where color is used as a safety measure to mark hazards in factories. The armed forces usually reject the color-blind.

What Causes Defective Sight?

HEREDITY. All the sight defects discussed above are unavoidable—although not irremediable—in the sense that they are believed to arise from hereditary causes or from growth and aging. Most students of visual defects agree that the common errors of refraction, where there is a blurring of part or all of the image on the retina, are of hereditary origin or represent differences in growth and development comparable to differences in height and shape of the head.

Some of these hereditary eye defects may not develop until later in life. An experienced eye specialist can often predict, on examining a very young child, that the child will probably be myopic in a few years, even though his vision is currently good. Observation of the shape of the eyeball or other characteristics of the eye structure, combined with knowledge of children's growth patterns, can produce an extremely accurate "educated guess."

Some of these built-in eye difficulties are purely transitory. Young children are not able to fuse the images from both eyes into one. Most acquire this ability before they begin first grade, but if a particular child's development is delayed in this respect, he should not be taught to read before his eyes are equal to the task. As in some other classroom situations, simply delaying a procedure until a child's maturity reaches the proper point can avoid much distress.

Whether one holds to the majority view of these defects or adheres to the belief of some that they develop as a result of misuse of the eyes, the handling of the problem will be the same. It is important to discover the defect early, to provide treatment if necessary and feasible, and to compensate for the deficiency as far as possible by glasses, good lighting, or adaptation of work to the limitations of the individual.

DISEASE. Among typical diseases of school-age children that affect the eyes are measles, chicken pox, and scarlet fever. Diabetes, high blood pressure, kidney disease, brain tumor, arteriosclerosis, smallpox, and tuberculosis also may affect vision. Though children with serious or contagious illnesses are kept at home, in some instances, a careful examination of the eyes should be made after a child's recovery from an infectious disease, before he is permitted to resume study. Decisions on these matters rest with the parents and family physician, who should be aided by school health authorities and classroom teachers.

Local inflammations of the eyes are common among school-age children. Infections are carried to the eyes by grubby fingers, with more or less serious results. Children with pinkeye (conjunctivitis) should be sent home and kept at home until they are completely recovered; this inflammation of the mucous membrane on the inner side of the eyelid is familiar to classroom teachers, who know well its ability to spread through a class.

It should not be forgotten that malnutrition is also a disease and can impair the sight. Children should be taught the importance of a well-balanced and varied diet. Not all malnutrition is a result of poverty; it occurs also among those who eat enough or more than enough to satisfy hunger, but whose diet is deficient in essential elements.

ACCIDENT. Carelessness or ignorance, though often contributing factors in accidents, can also result in visual damage when they lead thoughtless people to use dangerous chemicals or tolerate dangerous conditions. Dinitrophenol, a substance found in certain (less reputable) compounds advertised for weight reduction, is known to produce cataract, an eye disease which can result in blindness, in susceptible persons. Although ethical manufacturers will not risk their reputations by using any dyes expect those

specified as harmless by the federal Food and Drug Administration, some eyebrow and eyelash dyes may contain chemicals which cause ocular injury. (It should be noted that the harmful elements are found in dyes only; the commonly used mascara and eyebrow pencil are presumed to be safe.)

Accidents among children are best prevented by adequate adult supervision during study and play periods. Children are not notorious for their consciousness of cause and effect, and an excitable student waving a pen or a well-sharpened pencil may do damage he never contemplated. Protective goggles for certain types of shop work and safe procedures in laboratory work are important preventive measures. Playground supervisors should be aware of hazards to the eyes in impromptu fights and the like. Safety devices and regulations for games and sports should be strictly interpreted and enforced; rules for wearing helmets in football practice and against tossing the bat during baseball games should not be "sometime things." The school nurse, or a teacher trained in first aid, should provide immediate minimal treatment for foreign bodies in the eyes; if this is not effective, the child should be sent or taken home and the parents advised to seek medical care for him.

Good lighting, especially on stairs and in irregularly shaped rooms and corridors, can prevent many accidents. In addition, general lighting carefully chosen for its adequacy to the needs of the child and the task should be provided and maintained. However, the most meticulously planned lighting scheme for a schoolroom becomes ineffective if burned-out lamps are not replaced.

The subject of the school's role in preventing abuse of students' and teachers' eyesight will be discussed later in more detail.

Spotting the Symptoms

Experienced teachers tend to develop a "sixth sense" for signs of students' visual difficulties. Some teachers are alerted by certain symptoms observed during the course of the school day. Most teachers will recognize some, if not all, of these typical signs of visual difficulties, which occur even in children who have not yet learned to read:

1. Attempts to "brush away" blur
2. Unusually frequent blinking
3. Habit of rubbing the eyes
4. Squint connected with looking at distant objects
5. Frequent or continuous frowning
6. Tendency to stumble over small objects
7. Undue sensitivity to light
8. Red, encrusted, or swollen eyelids
9. Recurring sties
10. Inflamed or watery eyes
11. Crossed eyes
12. Complaint of headaches, sometimes even stomach-aches
13. General inefficiency.

Older children and those who have learned to read may show these additional symptoms which, when persistent, lead teachers to suspect visual difficulties:

1. Holding a book abnormally close to or far away from the face when reading
2. Inattention during reading periods or during chalkboard, chart, or map work
3. Evidence of difficulty in reading or in other work requiring close use of the eyes
4. Inability or lack of desire to participate in games requiring distance vision
5. Poor alignment in written work
6. Tilting head to one side or thrusting head forward when looking at near or distant objects
7. Nervousness and irritability when doing close work
8. Shutting or covering one eye when reading
9. Low morale or fatigue.

THE SCHOOL DOES ITS PART

From the time a child enrolls in school, the school is obligated to cooperate in helping him become a happy and efficient member of society.

Conditions that interfere with good seeing make the child's work in school more difficult. Various research studies point to uncor-

rected defects of sight as one of the causes of lack of progress among school children. Further, observation suggests that children learn more readily in well-lighted rooms than they do in poorly lighted ones, although further investigation of this subject is needed. One thing, however, seems certain: comfort contributes to people's contentment in doing their work. It is the school's duty to provide comfortable seeing conditions for its pupils.

An adequate school program must include not only the best possible visual conditions for general school work but also observance of safety measures to prevent the possibility of accidents wherever they might be likely to occur. Instruction in the care of the eyes should be included in the curriculum, and individual visual needs, capacities, and difficulties should be taken into account in planning the daily work. The school program should be arranged so that, as far as possible, classes requiring close work are alternated with those requiring little or no close work. The question of eye fatigue should be included in the considerations employed in determining what is a judicious amount of homework.

The school lunchroom's menus, presumably already carefully planned for general health, should include food elements that contribute to healthy eye function. Since these foods are not always the natural choice of secondary-school youngsters, extra effort in presenting and pricing certain dishes is often required to attract this group. It should be kept in mind that the school lunchroom often represents a unique opportunity to provide nutritional elements that may be lacking otherwise and to encourage desirable changes in dietary habits.

The health program should include provision for partially seeing children. They need as much association with other children as possible, both in work and in play, but their poor sight may make these relationships too difficult for them unless conditions are adapted to their handicap. All teachers should be familiar with the techniques of teaching visually handicapped children, for the current tendency is to assign such students to normal classes for the greater part of their work. Often they are assigned to specially equipped classrooms only for reading and other close work.

Since it is the likely place for the uncovering of symptoms of defective sight, the school has a special obligation to give close attention to this aspect of the child's general health. But the busy teacher, especially in secondary schools where most classes meet for an hour or less, cannot be expected to be the only source of information in this important matter. Every school should have regular procedures for screening children to detect sight problems.

Eye-Testing

The most familiar school procedure for eye-testing is the Snellen test, which records the ability of the eyes to see, first separately and then together, letters of different sizes at a distance of 20 feet in a well-lighted room. For children who have not yet learned to read, the capital letter "E" is turned in various positions; the child is then asked to point in the same direction as the "arms" of the letter. The Snellen test does not test near vision or ability to fuse images.

Full directions for giving the Snellen test may be found in *School Health Services,* a publication of the Joint Committee on Health Problems in Education of the National Education Association and the American Medical Association (see p. 52). Standard cards for testing sight may be procured from the National Society for the Prevention of Blindness (see p. 55) or from the American Medical Association (see p. 54).

Near vision can be tested by the use of a card printed with Jaeger test types. The individual selects the smallest type that he can read. The nearest and farthest points at which he can read with each eye separately are recorded.

Astigmatism is detected by means of the wheel chart, a circular diagram in which many lines radiate from the center. Although all the parallel lines are equally black, some look darker or lighter to the astigmatic eye. The location of the blurring indicates the location of the astigmatism. (To the normal eye, all the lines appear the same shade.) Occasionally, the test is indecisive, as in the case of a habitually inaccurate observer; if his general behavior suggests defective sight or if he complains of symptoms of strain, he should be referred to an eye specialist, who can apply more exact tests.

For all these tests, the cards must be uniformly illuminated by diffuse light without glare. The usual practice is to provide 10 footcandles of illumination (see p. 21), as measured by a light meter, on the test card.

Another widely used test is the Massachusetts Vision Test, developed by the Massachusetts Department of Health. A vision-screening device is used to test for visual acuity, hypermetropia, and muscle balance. Materials for the test can be obtained from Welch Allyn, Skaneateles Falls, New York.

Three sets of stereoscopic tests for screening the sight are available. All use cards viewed through a binocular device and measure such functions as visual acuity (both distance and near), muscle balance, fusion, depth perception, and color vision. The three sets are given with the Keystone Telebinocular, the American Optical Sight-Screener, and the Bausch and Lomb Ortho-Rater. Obviously, the equipment for these three tests is more expensive than for the others. Whatever tests are chosen should be used in the light of the evaluations that have been made of them.

Working with Parents

If a child's vision-screening tests at school indicate possibly defective sight—or even if he "passes," but nevertheless shows signs of inadequate vision—his parents should be advised that a more thorough examination should be arranged. Not all the children referred to a specialist will need glasses or other corrective measures, but the school must be ready to cooperate with parents and specialists in carrying out any recommendations made.

Care should be observed in the accuracy of the testing, so as to avoid unnecessary referrals. Then, tact should be exercised in advising the parents, so as not to cause undue alarm. Where poverty or other factors make the parents unable to implement the school's recommendation without aid, the school should be prepared to locate appropriate community resources to help. Vision-testing programs that produce only frustration and ill will are worse than none at all.

General consideration of and cooperation with parents is another of the responsibilities of the school in the area of eye welfare. Many parents will appreciate receiving a simple list of rules for studying and reading, including information on how to provide adequate lighting of study tables and desks at home.

The classroom teacher might also invite parents to school for a conference and demonstration of the right way to study. Another useful device is the display, during parent-teacher meetings, of posters on correct study habits and general rules of eye hygiene.

LIGHT

Correct functioning of eye and brain is the first requisite for seeing, but obviously the keenest human eye cannot see in total darkness. Light is indispensable to sight.

Even without total darkness, but below a certain level of illumination, we cannot see. Once that threshold is passed, however, the ease and accuracy with which we see depends upon a combination of variables.

One such factor is the brightness of the object seen—that is, how much light it emits or reflects. Except for things that give off their own light, everything is seen by reflected light. Brightness depends upon (a) the amount of light that falls upon an object and (b) the ability of the object to reflect light. Therefore, with a given amount of illumination and a neutral background, we find it easier to examine a light-colored object than a dark-colored one because more light is reflected by the former.

If there is decided contrast in brightness or color, or both, between the object and its immediate background, seeing will be aided. Since white reflects most light and black reflects least, the highest contrast in brightness is found in such combinations as black print on white paper.

The size of the object is also an important factor in seeing. In the same amount of light and with the same background, we can see a tennis ball better than a ping-pong ball if they are the same distance from our eyes. But, no matter how close we are to it or how bright the light, we cannot see an amoeba unless we look through a microscope.

But what makes it more difficult, then, to hit a pitched baseball than a teed-up golf ball, although the baseball is so much bigger? The answer is the time available to us for seeing the object: the golf ball stays right there, whereas the baseball must be seen quickly or it is too late. Similarly, a person in a swiftly moving train sees only a blur when he looks out at objects on the ground near the train. He has moved away too fast to see details.

Brightness, contrast, size, and time are all related; an increase in any one of them will compensate for deficiencies among the other three factors.

Unfortunately, we cannot always choose what we would like to alter when we have difficulty in seeing an object. Usually, however, the factor we can most readily change is brightness because, most of the time, we can control the amount of light falling on the object.

Natural Light

Before it is possible to plan good lighting, it is necessary to understand something of what light is and how it behaves. This is a large subject, complex and detailed, but since we are primarily concerned with illumination or light in quantity, we will deal here with the more familiar and general aspects of light.

Visible light is a form of radiant energy. Radiant energy is energy traveling in the form of electromagnetic waves. The length of these waves is measured in Angstrom units, one Angstrom unit measuring approximately four-billionths of an inch. Visible light rays range in length from about 3800 to 7200 Angstrom units, the length of the ray being related to the color of the light.

There are also longer, invisible light rays which include infrared, radio, and electric waves, and shorter rays, also invisible, which include ultraviolet rays, X rays, gamma rays, and cosmic rays.

Reflection

We see most things by reflected light. Unless light shines on objects, we do not see them, except for self-luminous objects (i.e., the sun or a light bulb). When light strikes a transparent surface, most of it is transmitted, or passed through, the surface. When light strikes a translucent surface, part of the light is transmitted and the rest reflected or absorbed by the surface. And when light strikes an opaque surface, part of it is absorbed and converted into heat, and the rest is reflected.

The way in which light is reflected depends upon the smoothness, shape, and color of the surface it strikes. This is an important consideration in planning lighting for good seeing.

SMOOTHNESS. If a surface is smooth and polished, it reflects light directly, or specularly. Direct, or specular, reflection means that if we draw a line at right angles to the surface, the ray striking the surface and the reflected ray will make equal angles with this vertical line. These angles are called the angle of incidence and the angle of reflection. Highly polished metals and mirrors reflect light specularly.

If a surface is figured in any way—corrugated, deeply etched, hammered, or pebbled—it spreads any rays it reflects. In spread reflection, the pencil of rays is spread out into a cone of reflected rays at slightly different angles but all in the same direction.

If a surface is apparently smooth but is actually composed of minute crystals or pigment particles causing a microscopic roughness, the reflection is diffuse. Each single ray striking the infinitesimal surface of each particle behaves according to the laws of reflection; but as the surfaces of the particles are in different planes, they reflect the light at many angles. With perfectly diffuse reflection (seldom attained in practice), the light is distributed so that, if the reflected beams are plotted, they fill a circle. Flat paints and mat-finish papers provide this kind of reflection, which is most useful where wide distribution of light is desired.

Many surfaces of materials in common use exhibit a combination of all three reflection components. This is called compound reflection. In some of these compounds, one or two types predominate. Specular and narrowly spread reflection cause the "sheen" on semigloss paints, some textiles, and snow fields. Porcelain enamel and glossy paints, which are composed of a shiny finish over a mat base, combine diffuse and specular reflection.

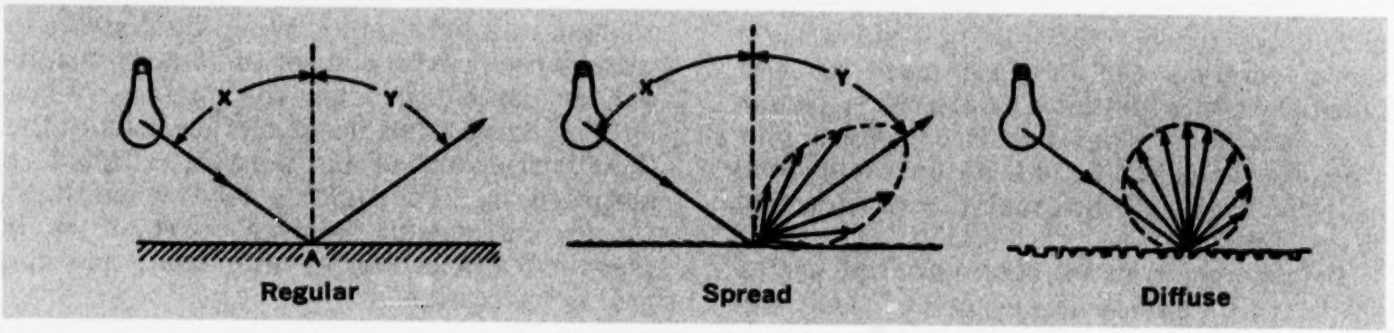
SHAPE. The shape of the surface also influences the way light is reflected from it. A perfectly flat piece of shiny silver of consistent thickness will reflect your image faithfully, but if you have ever looked at your image in the back of a silver spoon you know how oddly your face is distorted by the curve of the surface. Similarly, the mirrors in amusement parks, those that show you yourself pinheaded and enormously fat or strung out like a piece of spaghetti, produce these distortions because of ripples in their surfaces.

Mirrors can be shaped to reflect objects so that the images we see are smaller or larger than the objects. Also, in auto headlights, the reflectors are oriented so that light striking their surface will be reflected nearly horizontally and sent out in a beam.

COLOR. Even though the difference in length between a red and a yellow wave is tiny, this difference is still great enough to produce distinct reactions in the cones in the eye, which enable us to perceive the difference. But the seeing of color does not depend entirely on the wavelength. Some objects absorb certain of the wavelengths of light directed at them, leaving only those wavelengths reflected to the eye to be seen as colors. A white sheet of paper, for example, reflects all colors when white light strikes it. If there is no light at all, the paper will look black because it is reflecting no color to the eye. In red light, the paper will look red because only red light is being reflected from it.

In certain insect wings or bird feathers or in the iridescence of mother-of-pearl and opal, color is seen not because of pigment

FIG. 7 Types of Reflection



but as a result of the light reflected selectively. This effect is emulated by theatrical designers and lighting experts, who use colored lighting to provide shadows and appearances of depth and color in scenery and costumes.

We should be careful to distinguish, however, between color in light and color in paint. A green light is green because it is emitting waves of a certain number of Angstrom units in length. Green paint, on the other hand, is seen as green because it is absorbing the red and blue waves in the white light directed at it and reflecting only the green waves back to the eye. If you mix beams of red and green light in equal amounts, you will see yellow light; but if you mix red and green paints, the result will be gray or black, because all the waves for primary colors will be absorbed from the light striking the paints, leaving nothing to reflect.

An amusing color illusion, called the afterimage, apparently results from retinal fatigue, in which the color-receiving nerve endings in the eye become weary after steady exposure to strong primary colors. It can be demonstrated as follows:

Draw a picture in blue-green crayon on a piece of bright red paper; the contrast should be marked. Now look fixedly at one point of the picture for a minute, then quickly transfer your gaze to a piece of blank white paper. Gradually, the picture will seem to reappear on the blank paper, but in reverse. The background will look blue-green, and the picture will seem to be drawn in red.

Refraction

Earlier in this book, we talked about refraction—the bending of light rays as they pass from one substance to another of a different density—in the course of our description of the process of seeing (see p. 7). Later (see p. 8), we discussed the defects in seeing that result from the eye's errors of refraction, and we noted how they could be corrected.

Now that we have learned something about light rays and how they travel (see p. 15), we can ask this question: Why do light rays bend?

Light bends as a result of a change in its velocity. The speed of light in a vacuum is calculated at about 186,300 miles per second. When passing through water, however, light travels only about three-fourths as fast. The speed of light traveling through other transparent substances has also been measured. The ratio of the velocity of light in a vacuum to its velocity in another transparent substance is the index of refraction of that substance.

The degree of bending of light when it travels between substances of different density depends upon the relative densities of the two substances (whether it is going from more density to less, or vice versa), the wavelength of the light, and the angle at which the light strikes the surface of the medium. Whenever a ray of light strikes a transparent substance at an angle, part of the ray is reflected and part refracted; the greater the angle, the larger the amount of reflection. The part of the light that is not reflected is refracted at the surface of the medium.

But, when light passes from a substance with a high index of refraction to another with a lower index, it is possible, depending on the angle at which the light strikes the surface, that all of the rays may be reflected. We see this when clear water, lighted from a certain direction, acts as a mirror.

Normally, however, all these conditions are not met, and we see refracted light, not reflection, in a transparent medium; if, for example, you lean a long drinking straw into a small glass of water, the straw will appear to be bent at the point where it enters the water. This optical illusion results from the difference in refraction of light rays coming from the upper part of the straw, traveling through air, and those from the lower part, traveling through water.

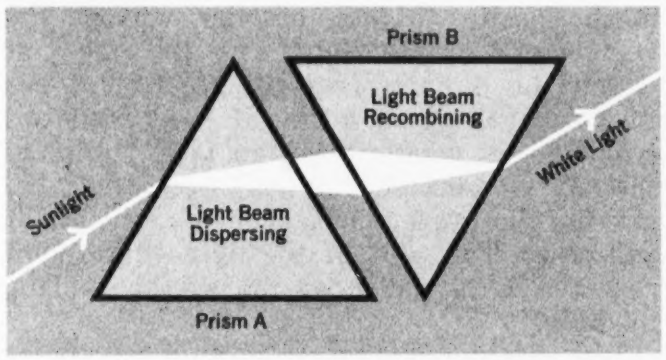
The colors our eyes can see appear in a certain order, the same order as the natural rainbow. You can see a demonstration of this spectrum by means of a prism, a solid triangle of clear glass. If you hold a prism in the rays of the sun and twist it around slowly, you will find, at one point, that a band of colors can be seen. These will be in the same arrangement as the visible light rays in the electromagnetic spectrum.

This separation of a beam of light into its component colors is called dispersion. It occurs because the light waves of varying length which make up the white beam of

sunlight are refracted by slightly different amounts as they travel through the glass.

Isaac Newton, the seventeenth-century scientists who first discovered that the spectrum could be produced by interrupting a beam of sunlight with a prism, proved that white light was indeed made up of all these colors by arranging a second prism so that it would recombine the colored beams into a white light. (See Fig. 8.)

FIG. 8 Refraction



A glass aquarium filled with water will act as a prism if the light is directed at it correctly. So will the corner of a piece of plate glass or any other part of a piece of glass where two plane surfaces meet. Accidental prismatic effects are seen in fine sprays of water, when light strikes at such an angle that the droplets act as prisms.

Another simple demonstration of the bending of light rays is shown by this experiment:

Place a coin at the bottom of a pottery or china soup bowl or other dish or pan with opaque sides. Put your eye on a level with the bowl, so that the coin is hidden from your view. Then have someone pour water slowly into the bowl while you hold your position. Soon you will see the coin, although it is not floating on the water and neither you nor the coin has changed position.

What has happened, of course, is that you are seeing an object where it is not, because the light ray traveling from the coin to your eye is bent as it moves from water to air. But, since the eye sees in a straight line, the image of the coin is seen at the surface of the water, whereas the coin itself is still at the bottom.

Glass can be deliberately shaped in various ways to produce corrective lenses by refracting light (see Figs. 5 and 6 on p. 9); sometimes, as in glasses for athletes and children, other transparent substances—quartz or fluorite, for example—are used instead of glass because they can be shaped as satisfactorily, but are not as likely to be broken.

A lens can be shaped so that it will concentrate light rays (convex lens) or spread them (concave lens). The extent of these powers can be indicated in part by a simple demonstration: An ordinary magnifying glass, which is a double convex lens, held in a beam of sunlight over a piece of paper, will so concentrate the light rays from the sun that enough of them will be absorbed and converted into heat to make the paper catch fire. Since dark colors absorb light, a pencil smudge on the paper will speed up the process by focusing the light rays.

This ability of lenses to refract light serves us in many ways other than for the correction of sight defects. Lenses, alone or in combination with mirrors, are used in telescopes, bringing the vast distances of space within our vision, and in microscopes, opening up the unseen world to our eyes.

MAN-MADE LIGHT

No one is sure exactly when the idea of manufacturing light was born.

Perhaps it happened one day, long before anyone began to write down history, when some early ancestor of modern man looked up from his task—sharpening a stone by scraping it against another—and discovered, to his exasperation, that the sun was going down and he would be forced to wait until morning to continue his work. Maybe they had fireflies then—and maybe the same man, or a descendant of his, decided to capture a few and see whether he could get some light into his cave.

As anyone who has caught a jarful of fireflies on a summer evening has discovered, they are not very cooperative. Probably, therefore, our primitive man had to learn to resign himself until that most important day in the history of our race—the day fire was captured or produced. Truly, much was gained with that discovery: a way of cooking and preserving food, life-giving warmth

against the cold, protection against wild beasts, and the gift of the formerly lost hours of darkness.

Light from fire, in one variation or another, was in use for thousands of years. We know that the ancient Romans used torches. We also know that the candle was invented over 2000 years ago.

Although the candle gave way in some places to the oil lamp, and the oil lamp and its fuel were continually varied, improved, and refined, man-made light remained comparatively simple and portable. It is said that the Chinese had used natural gas for illumination as early as 900 A.D., but, so far as most of the world was concerned, no new light source was introduced until the nineteenth century, when manufactured gas was first used.

Gas lighting, the beginning of manufactured light from a centrally supplied source, was quite widely used by 1850. Electric arc lights began to replace gas lights for street lighting when the invention of the Gramme dynamo in 1870 supplied an adequate source of electric energy. Gas lighting and the new electric lighting ran a neck-and-neck race for a while. Although the incandescent electric bulb was then available, the invention of the Welsbach mantle in 1883 reinforced the use of gas lighting for a time. By the close of the last century, however, electric lighting was on its way toward its present complete domination of commercial and home lighting.

The Incandescent Lamp

Broadly speaking, the incandescent lamp —what we call the "electric bulb"—is made possible by the relationship between heat and light and the comparative ease with which one can be converted to the other; we have seen this in reverse in discussing solar heating of houses and in demonstrating how a magnifying glass can set fire to a piece of paper as well as in describing the electromagnetic spectrum.

The word *incandescent* means "white, glowing, or luminous, with intense heat." Thomas Alva Edison's first practical incandescent lamp in 1879 involved, quite simply, the heating of a filament, or fine wire, until it gave off a glow. The filament was heated by an electric current and was housed in a glass globe from which oxygen had been eliminated.

Originally, vacuum globes were used, but nowadays electric bulbs in ordinary use contain an inert gas, such as argon, with a small added percentage of nitrogen. Earlier filaments were made of carbon, but the evaporation of carbon at high temperatures made its efficiency low. Eventually, therefore, tungsten replaced carbon as a filament material, after difficulties in its application had been overcome.

There are many varieties of incandescent lamps, different in shape, size, structure, and even color, depending upon the use to which they are to be put. The fact that they are in such general and differing use is due to some rather attractive advantages. The bulbs are, as a rule, interchangeable, and it is easy, therefore, to obtain the correct amount of illumination by simply changing to bulbs of the desired wattage. Since lighted bulbs are brilliant and are virtually a point source of light, they must be shaded for eye comfort, but a wide variety of lighting units and shades is available to provide the desirable light. Incandescent bulbs are inexpensive and easy to operate, and they give light instantaneously.

Incandescent lighting also has its disadvantages. One of these, which is not a serious handicap in the general, everyday use of incandescent lighting, is the effect this type of lighting has on color. Under the light from incandescent lighting, yellows and reds are intensified, and blues and violets are grayed. However, since people have long been accustomed to this flame-colored lighting, the changes in color do not seem offensive, and most people find the light pleasing and comfortable.

Another disadvantage of the incandescent bulb is that such a large proportion of its output is radiant heat, as compared with the output of the fluorescent bulb. This may prove to be a problem where there is air conditioning or an annoyance when placed close to a person at work.

The Fluorescent Lamp

In part as a result of a search for a cooler and more efficient light—like that of the firefly, which has been estimated at 98-percent efficiency—scientists have developed

other kinds of lamps. One of these is the electric discharge lamp, in which a flow of electric current through a gas or vapor causes it to give off light. The process depends on the fact that if a gas is ionized it will conduct an electric current; in doing so, it radiates energy.

Common forms of the electric discharge lamp include the following: carbon arc lamps, used in the projection of motion pictures, where extremely high brightness is necessary; mercury lamps, used in street and outdoor lighting because of their relatively long life; and neon lights, used in display advertising and, recently, in highway warning signs.

The fluorescent lamp, which is a variation of the mercury lamp, is based on the phenomenon of fluorescence, in which certain chemicals become luminous under ultraviolet radiation.

People who have few or no freckles under ordinary daylight will, under ultraviolet light, sometimes be startled to find that their skin is heavily freckled; this is because the skin fluoresces slightly but the freckles remain dark and therefore show up where their presence was previously undetectable. Some substances, like ordinary skin, absorb energy from the ultraviolet wavelength and emit it as a visible wave, whereas others, like the freckles, do not.

The inside of the fluorescent lamp—usually a long glass tube—is coated with one or more chemicals called phosphors, which fluoresce brightly under short ultraviolet light. The tube is filled to low pressure with an inert gas to which a little mercury is added. When an electric current passes through the gases between the electrodes at the ends of the tube, invisible short ultraviolet rays (2537 Angstrom units) are given off. These, in turn, act upon the phosphor coating to produce the desired light.

There are phosphors known to give off each of these shades of light: blue, blue-white, green, orange, yellow-pink, and pink. They can also be mixed. Thus, both the amount and the color of the resultant light can be controlled.

Ordinary glass is used for the tubes in fluorescent lights: this prevents the passage of the short ultraviolet rays. In sun lamps, where a controlled exposure to ultraviolet radiation is desired, quartz is used for the tube instead of glass, so that the rays will be passed through.

However, enough radiation is given off by the fluorescent lamp to interfere with radio reception: for this reason, it will be found helpful, where interference is noted, to move the radio farther away from the fluorescent lamp. For interference which is transmitted through the power line rather than through the air, filter circuits may be employed to reduce or eliminate the interference. Many fluorescent fixtures are already equipped with such filters.

There are other initial problems in the use of fluorescent lighting. The unit must include a mechanism called the ballast, which is necessary to control the electric current. Unless the unit is carefully mounted, the ballast may produce a humming sound.

Wattages cannot be readily changed in fluorescent lighting, as they can be in incandescent lighting, because of the necessity of using different ballasts. One may get more light by using a longer tube, by using more tubes in an already installed row of tubes, or by adding another row; another way is to use higher-output tubes (such as "high-output" or "extra-high-output" lamps), with different ballasts in each case.

Since adaptations require procedures far more complicated than simply changing a light bulb, fluorescent lighting should be planned from the outset to provide for both currently needed and potentially needed illumination. The installation is costly, and account must also be taken of an initial light loss of 10 percent during the first 100 hours of use and a more gradual loss over the later life of each tube. These losses add up to a total of about 25 percent over the 7500-hour life of an average 40-watt tube.

However, these initial costs for installing fluorescent lighting are partially or completely (depending upon the cost of electricity in a given area) compensated by the fluorescent unit's lower consumption of electricity for the same amount of light. Where there is air conditioning, the fact that the tubes are cool can result in considerable saving in costs.

Another advantage of fluorescent lighting derives from its variability in color. Fluorescent lighting can be made to approach the color composition of average daylight at about noon on a clear day; such light is com-

monly used as a standard to judge materials. Tubes may be chosen, however, to emphasize either warm or cool colors, as desired.

In designing and installing fluorescent lighting units, attention must be given to shielding the eyes by the use of baffles or translucent materials. Although bare fluorescent tubes are brighter than the highest recommended brightness for school lighting, they are much less bright per square inch of surface than the ordinary incandescent bulb (since the former distribute light over considerably more surface). This superiority is advantageous if care is taken to see that the light is distributed evenly and comes from as large an area as possible.

A LIGHTING DICTIONARY

Light, like any other physical quantity, must be able to be measured accurately if progress is to be made in the study and use of the subject. Without terms of measurement, discoveries cannot advance on the basis of knowledge gained before because there is no way to pass on the information.

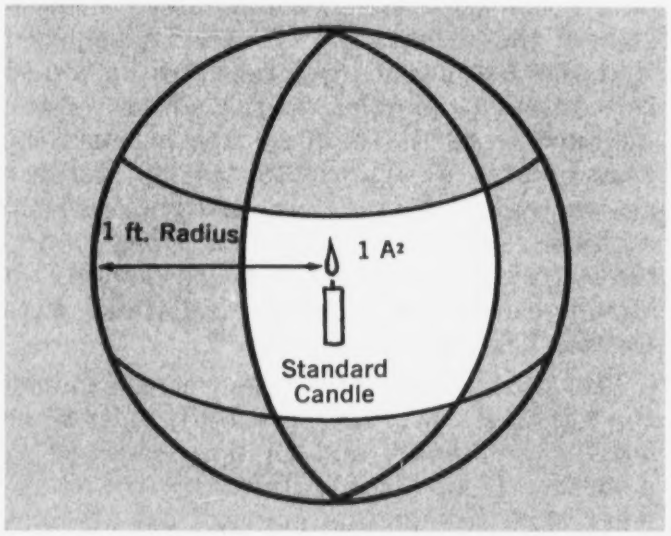
Since man's need to measure brightness occurred long before the invention of electricity, the unit of measurement for the intensity of a light source was based on the candle. In order to be sure that everyone was talking about approximately the same thing, a *candle* was defined as the amount of light emitted by a physical candle made according to certain specifications and burning under certain controlled conditions.

By international agreement, an equivalent for this amount of brightness was established; *candela*—the Latin word for *candle* —was the name recommended for this unit. Candlepower is the general measure, then, for intensity of light: it is expressed in terms of candles or candelas, just as temperature is expressed in terms of degrees.

The quantity of light on a surface is measured in units called footcandles. As the name indicates, a footcandle is the amount of light deposited on a surface that is at all points one foot away from a one-candle source of light. To get an approximate idea of how much light there is in one footcandle, hold a newspaper page upright one foot away from a lighted candle, with no other illumination. Sunlight at noon my provide as much as 10,000 footcandles of light, whereas the light in the shade, even on a sunny day, falls to about 500 footcandles.

A footcandle of illumination may also be be described as one lumen per square foot. The lumen is the unit of measurement for the flow of light in all directions from a source of one candlepower. The best way to understand the lumen is to imagine a perfectly transparent hollow sphere with a radius of one foot; at the exact center of the sphere is a light source of one candlepower. As the light radiates from this source, it travels outward in all directions, so that the whole internal suface of the sphere is lighted equally. The lumen is the amount of light that *strikes* any square foot of the sphere in these circumstances. The amount of light *received* by any square foot of the surface is one footcandle. (See Fig. 9.)

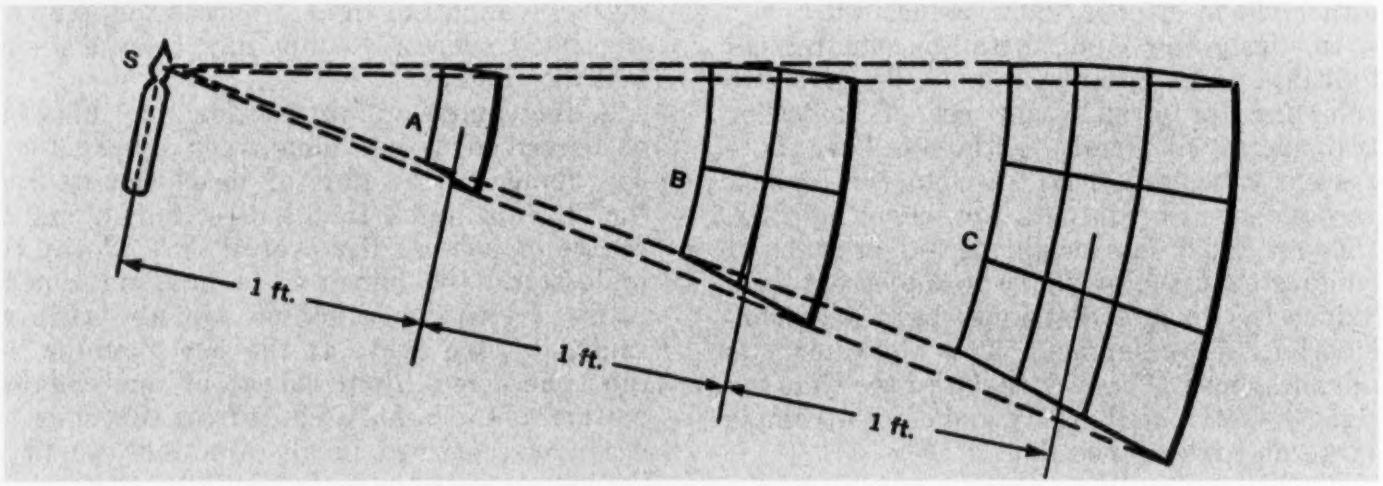
FIG. 9 Footcandle



Since we are able to calculate the surface area of a sphere with a radius of one foot, we know that the total area is 12.57 square feet. (The formula for the surface area of a sphere is $4\Pi r^2$.) As we have seen that there is a flow of one lumen to each square foot of the surface, we know a one-candlepower source provides a total of 12.57 lumens.

If the radius of the sphere should be doubled, the surface area would then be 50.28 square feet, or four times as great as the original sphere. Now, even though any point on the surface is only twice as far away from

FIG. 10 Inverse Square Law



the light source as it was in the first sphere, the total area that is lighted is four times greater—so the amount of light striking any square foot of the second sphere is only one-fourth lumen.

The inverse-square law of illumination states the fact that we have seen demonstrated in the example of the two spheres: that the amount of light reaching an object falls off in proportion to the *square* of the distance from the light source because the area covered grows greater as the distance grows greater. The amount of light reaching an object was cut to one-fourth when its distance from the light source was doubled; it would be cut to one-ninth if the distance were tripled. (See Fig. 10.)

We have discussed three measurements for light: at its source (candle), as it flows outward (lumen), and as it is received at a surface (footcandle). However, as we have learned earlier in this manual, not all light shining on a surface is perceived by the eye.

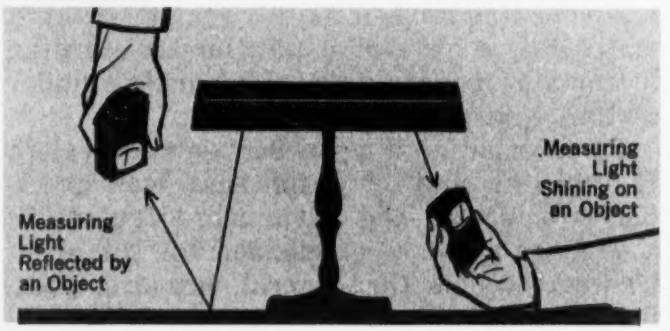
The unit of measurement for the luminance of an object—that is, the amount of light reflected from it—is the footlambert. A theoretical, perfectly diffusing surface giving off light at the rate of one lumen per square foot (which means that it would be lighted to one footcandle) would have a brightness of one footlambert in all directions. Since there is actually no such perfect surface, the number of footlamberts is in reality equal to the number of footcandles illuminating the surface multiplied by the reflectance of the surface.

Reflectance is the ratio between the light shed on a surface and the light reflected from it. If an object receives 50 footcandles and reflects 30, its reflectance is 60 percent.

Thus, when a diffusing surface with a reflectance of 50 percent is lighted to two footcandles, its brightness is one footlambert.

Reflectance is determined by the use of a light meter, which records, usually in footcandles, the amount of light falling on a light-sensitive photoelectric cell. Light meters may be used for measuring either the amount of light from a source or the amount reflected by a surface. (See Fig. 11.)

FIG. 11 Use of the Light Meter



In many localities, light meters are made available to schools, on request, by the electric-power company in the region. Small meters are produced by Weston Instrument Company, General Electric Company, or Photo Research Corporation.

Photographic exposure meters may also be used for measuring light. Many give readings in terms of footcandles; others are accompanied by a conversion table.

A few precautions will help in using a light meter successfully:

1. Be sure the light-sensitive cell is not obstructed.
2. Be sure no shadow falls on the meter.
3. Be sure there is no shadow on the surface when taking a reading of reflected light.
4. Hold the meter on the same plane as the surface being tested. For example, if measuring amount of light on a book, the sensitive cell of the meter should be at the same angle as the surface of the book.
5. If measuring the level of lighting from a single source, be sure to eliminate all other sources of light.
6. When taking a reading for a large surface, it might be advisable to take several readings at different points and compute the average.

LIGHTING IN USE

You can work in less than optimum lighting conditions, just as you can read a newspaper in the poorly lighted interior of a bus; common sense, however, indicates that neither is a very good idea. Studies have shown that our off-the-cuff observations of this fact are correct: when lighting is not adequate for a particular seeing task, mental and physical responses are slower and less precise. If these poor conditions are continued for any length of time, motivation and morale suffer.

The lighting experts have computed for us the quantity of light desirable for some given situations. But there is more to adequate illumination than mere quantity of light. Other problems must be solved if we are to meet the requirements dictated by what we have learned about the structure and functioning of the human eye and the possibilities and limitations of different kinds of lighting equipment.

A major problem in effecting good lighting conditions is the elimination of glare, which may be defined as any light reaching the eyes in a way that causes seeing discomfort or inefficiency. Direct glare may result from a light source that is too large, too bright, or inadequately shielded. Reflected glare occurs when shiny surfaces reflect the image of the light source.

Direct glare can be most easily eliminated by proper shading of the light sources toward the eyes and toward the visual task. Reflected glare can be tempered by avoiding shiny surfaces in the work itself or at other points within the field of vision. When we are unable to make these desirable changes—if, for example, the material we must read is printed on glossy paper—we can use our knowledge of the laws of reflection to rearrange the physical relationship between our work and our light sources so that the degree of discomfort is reduced as far as possible.

A second problem found in ordinary working conditions where there is adequate light is excessive difference in brightness. Although the eyes are capable of adjusting to amounts of illumination varying from starlight to brilliant sunlight, it takes time for the pupil to adjust in size and for the retina to adjust in sensitivity. Over a period of time, we suffer discomfort and possible fatigue if our eyes are forced to adjust to widely differing brightnesses reaching them from different areas at the same time.

Most of the uses to which we put our eyes while we are indoors fall into two classes: "heads-down" tasks and "heads-up" tasks. Such activities as watching television are described as tasks; even though we may be watching for pleasure, our eyes are working at a task.

TV-viewing is a heads-up task because the seeing is done at or near the horizontal at an object some distance away. Homework is a heads-down task because the eyes are usually directed downward at a distance of about arm's length. In both cases, there is a small central area in which the eye sees in detail and a larger cone-shaped area representing surroundings to which the eyes are sensitive at the same time.

Since the eyes rove constantly, this area of vision moves about the room even when the individual is not deliberately shifting his vision. This is another reason for the desirability of having all visual surroundings as uniform in brightness as possible, to avoid excessive changes. This condition is not al-

ways feasible to attain, but it is advisable to try to achieve it as closely as is practical.

In general, illumination should be directed throughout a room so that the darkest areas have no less than two-thirds the illumination of the lightest areas. This may be accomplished through controlled over-all lighting or through combinations of over-all and local lighting. Specific brightness ratios for classrooms are given in Table V on page 38.

Although some shadow is needed in order to perceive detail, too many and too-dark shadows may result in confusing silhouettes. Diffuse lighting usually results in the best proportion of light and shadow. A simple test of diffusion in lighting is to hold a pencil about three inches above a work surface: if there is no shadow or if the shadow is blurred, diffusion is good.

By judicious use of the variety of lighting arrangements available, we can provide almost any lighting effect desired. Complex luminaires—complete lighting units consisting of a lamp or lamps and the parts designed to distribute the light, to position and protect the lamps, and to connect the lamps to the power supply—and simple light sources, portable or built-in, can be combined to achieve the necessary results, as can light bulbs and fluorescent tubes. Architecture, interior decoration, and maintenance factors play their parts in the distribution of light, which generally falls into the following patterns (see Fig. 12):

INDIRECT LIGHTING. Because less illumination results from a given amount of electricity than in direct lighting, a frequent mistake is providing an insufficient quantity of light. Allowance should be made for the fact that some useful light is lost by absorption into the reflecting surfaces. Units must be mounted and distributed properly to avoid the possibility of reflected glare from the ceiling. As some people object to seeing the silhouette of the luminaire against the ceiling, the units are often light-colored or have a slightly translucent bowl. Efficiency depends to a large degree upon cleanliness of walls and ceiling as well as of the units themselves, so maintenance may be a problem.

SEMI-INDIRECT LIGHTING. These units utilize the ceiling as the main source of light. Maintenance is important.

GENERAL DIFFUSE LIGHTING. Most of the light falls directly on the working surface, with a considerable amount from the ceiling.

SEMIDIRECT LIGHTING. Some light is received from the ceiling, but the greater part comes directly from the equipment to the surface. Maintenance is important.

DIRECT LIGHTING. Although it provides wanted illumination with less cost for current, it is also most likely to produce glare. The likelihood of troublesome brightness differences may be reduced by keeping the luminaire itself and the ceiling, walls, floor, and equipment very light in color. The unit should be mounted high or be well shielded. Ceiling and walls play little part in reflecting light, so frequent cleaning is required only for the unit itself.

LIGHT IN THE HOME

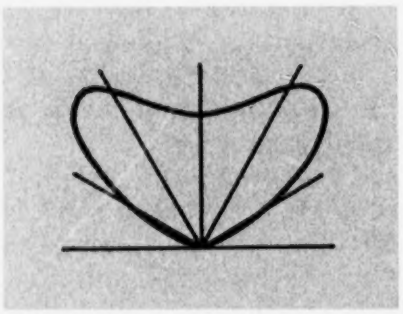
The home, more than any other day-to-day environment, requires a wide variety of lighting levels. In the home, unlike the schoolroom, the people are often of widely differing ages; unlike the workshop or industrial facility, individuals are often engaged in very different tasks at the same time. In the business world, the work area and the shop or front office are separated and can be lighted and decorated in accord with their separate purposes; in the home, beauty and utility must be combined. There, also, visual tasks are regularly performed during both daylight and darkness hours.

Daylight

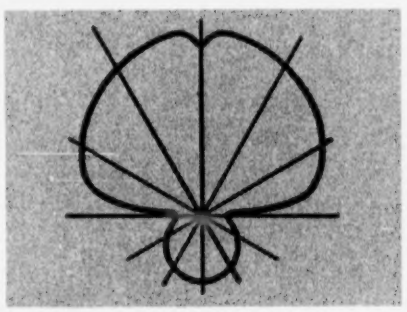
Daylight should be both abundant and well controlled to avoid visual difficulties resulting from poor lighting. An adequate number of large windows admitting plenty of light should be combined with effective means of curtaining and shading to avoid glare. In planning a house, location of windows and other areas that admit light should be carefully calculated, with direction of exposure, size, position, and shape all taken into account.

With the current trend toward large windows and even whole walls of glass, control of daylight is effected from the outside and

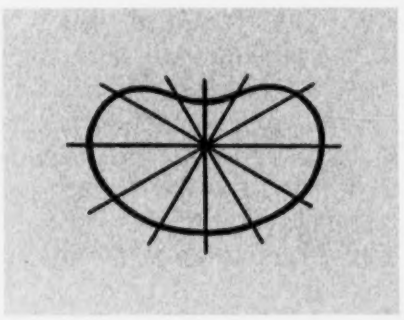
Types of Lighting **FIG. 12**



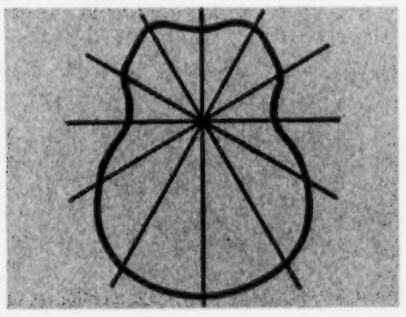
A. Indirect Lighting. Ninety to 100 percent of light is sent upward toward the ceiling, from which part of it is reflected downward. When well distributed over the ceiling, this gives a restful, glare-free effect, with shadows soft or nonexistent. Indirect lighting tends to give an over-all appearance of flatness to a room, but makes a good schoolroom light and combines well with other types of lighting.



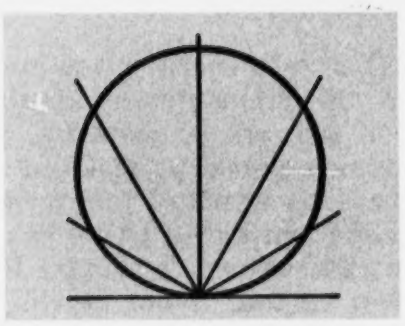
B. Semi-Indirect Lighting. Sixty percent or more of light is sent upward, the rest downward. Semi-indirect lighting produces more light per watt than indirect lighting, but both shadow (particularly with incandescent lamp) and glare are increased unless units are designed carefully.



C. General Diffuse Lighting. Forty to 60 percent of light is sent upward, 60 to 40 percent downward. More light per watt is provided than in semi-indirect lighting, but corresponding increase in glare and shadow, if incandescent, makes it difficult to use in the classroom unless carefully designed for direct and reflected glare problems. However, it is good for halls and washrooms.



D. Semidirect Lighting. Sixty to 90 percent of light is sent downward, the rest upward. Much usefulness depends upon how well the lighting is designed and mounted. Semidirect lighting is not a good study light for school use, but may be used in halls, washrooms, and locker rooms.



E. Direct Lighting. Ninety to 100 percent of light is sent downward toward the work surface. Unless unit is of large area, it is difficult to provide highly diffused lighting. Direct lighting is useful for local lighting where a high level of illumination is needed for such a particular task as industrial or school shop work.

the inside of the house simultaneously. Outside louvers, roof overhangs, baffles, exterior screening, prismatic glass, and glass block are some of the architectural means of controlling light from the outside. Glass blocks and panels, plastic sheets and panels, and other light-directing transparent materials must be used above head height, to reduce the brightness of direct sunlight when viewed from within the room. Properly employed, light-directing glass increases illumination at the far side of the room. As it is easy to maintain and attractive, this has become a popular means of general lighting in new homes, particularly in entrance halls and other areas where diffused daylight is desirable.

However, not all of us are lucky enough to have complete choice of location and design, even when planning a new home. Compromises are dictated by financial and other practical considerations, but some effective combination can nearly always be achieved to bring about the desirable ratio of daylight and control.

The traditional vine-covered cottage was picturesque, but its ivy may have been no boon to good seeing indoors. Nowadays, landscape architects have shown the way in designing methods of planting that blend beauty and utility. A planting pattern arranged so that pleasing shadows are cast but light is not cut off can be carried out by the do-it-yourself gardener.

Also, for the older home, awnings can be added, relatively inexpensively, to provide exterior shading where major architectural changes are impossible and landscaping is impractical or ineffective. These devices are also useful in keeping out summer heat; even where air conditioning is used, it is desirable to reduce the load on the cooling machinery.

In the interior of the room, light control is possible by many devices or combinations of devices, providing choices suitable for all budgets and tastes.

ROLLER SHADES. A generation ago, many homes had a pair of roller shades at each window; a light-colored one, white or ivory, could be pulled down to diffuse light and keep out direct sunlight, and a black or dark-green shade could be used to darken a room in the daytime for sleeping or to shut out disturbing outside lights at night.

These shades were inexpensive, but they were also not very sturdy; they were operated by a flimsy spring mechanism that broke rather easily, and the shade itself was inclined to tear after fairly constant use. Another disadvantage was that it was impossible to shut out light without shutting out air, an unhappy fact that made for stifling rooms in summer.

VENETIAN BLINDS. Thus, when Venetian blinds became available, they were hailed enthusiastically because of their capacity for dual adjustments for light and air. As they continued in use, they were modified so that they became easier to clean and sturdier of construction; at the same time, their price became competitive. Housewives who had been forced to close every window in the house before going out on a summer afternoon, lest a sudden shower leave all their window shades in tatters, delighted in the new blinds, which could be tilted to repel the raindrops and, in any case, could survive a considerable downpour.

Lately, however, the housewife has begun to reconsider. The Venetian blind, for all its advantages, turned out to be a considerable dust collector. And, although it was sturdier in general than the roller shade, when its complex of ropes frayed and wore out, replacing them was usually a time-consuming and frustrating task that tried the handyman talents of some husbands and the tempers of most.

Currently, although Venetian blinds are still most used, roller shades, especially a more expensive and attractive "decorator" variety sometimes covered with wallpaper or other designs, are seen again. As they are usually made of more expensive material, the new variety are not so flimsy as the old-fashioned roller shades. In some rooms, such as the master bedroom, where there is usually no great need for the distributed daylight offered by Venetian blinds, the roller shades save a good deal of dusting and add to the decor.

CURTAINS. It is surprising how much daylight is cut off by curtains, even when they are made of very sheer material. For this reason, curtains should be made of an open mesh weave, such as net or marquisette, and they should be white or a pastel color. Even with these restrictions, however, the ordinary window curtain is not flexible enough

for good light control unless it is hung so that it can be drawn to the sides. Since window curtains are made of thin fabric, they do not usually lend themselves very practically to this method.

DRAPES. Side drapes, often used with a valance and ruffle or strip of material across the top of a window, are usually desired because of their decorative appearance. Lighting experts and interior decorators are in agreement that side drapes should not be hung over the glass area of the window.

Draw drapes, which pull all the way over to the sides so as to leave all the glass area available and which also can be closed to cover the entire window, have the double advantage of providing maximum availability of daylight and a surface for the diffusion of light at night. With the large windows in popular use, this may represent a rather heavy expenditure in costs of drapery material and hardware, but it is also a major interior decoration feature.

Both side and draw drapes may be used with either Venetian blinds or glass curtains and are occasionally used with both.

CAFE CURTAINS. This informal window treatment consists of separate sets of short drapes for the upper and lower halves of windows. They are hung on rings or some variation thereof, which slide easily, so that they may be opened and closed by simply pulling them gently along the rod. This does away with the more complicated rods and slides required for draw drapes. The top half of the café curtain may be pulled to the side, allowing light to fall on the far side of the room, while the bottom half is left closed for privacy. The procedure may be reversed to effect particular lighting arrangements, as, for example, when the top level is left closed to avoid the glare of the sun and the bottom half opened to daylight shadowed by trees or overhang.

Café curtains are economical because they are easy to install and to clean. Also, they require little skill to sew, and attractive effects can be achieved with inexpensive material. They are especially popular for kitchens, children's rooms, and playrooms.

Electric Light

In the vast majority of American households nowadays, the automatic response to a day of cloudy skies or to the coming of night is the flick of a switch. Candlelight is used usually for decoration and sometimes for outdoor dining. Such other forms of lighting as kerosene lamps are used in emergencies or for such special activities as camping trips.

In designing or changing electric lighting for the home, the aims to keep in mind are these:

1. Efficient seeing
2. Comfort
3. Beauty
4. Safety
5. Adaptability.

Decorative lighting may be of any type desired, so long as it does not create harmful glare. The possibilities are limited only by the imagination of the architect and the homemaker and by their ingenuity in utilizing standard equipment. An atmosphere of warmth, friendliness, and relaxation can be combined in the home with optimum conditions for visual performance.

In older homes, shortcomings in lighting can be offset by installing new lighting units and by adding portable lamps. Anyone planning a new home should explore the advantages and disadvantages of fluorescent and incandescent lighting. The necessity of adequate wiring and the importance of interior decoration in good home lighting should also be kept in mind.

For most people, the best lighting selections are portable or easily attached luminaires of simple lines, soft colors, and recommended construction. Portable luminaires can be tried in various combinations without the expense or physical effort involved in changing permanently installed lighting units. Portable units are also economical for those who live in rented homes and need easily installed and attractive light sources.

All consumers should be cautioned about using specially constructed and unstandardized equipment. Such equipment may not be easily repaired or replaced. Standard items are more readily obtained when needed and have, in the majority of cases, been approved by the Underwriters Laboratory, which tests electrical equipment for safety.

The basic requirements for safe and efficient home lighting are the same as for lighting in most other situations. In each room there should be quality lighting with higher

levels of illumination where they are needed for specific tasks, but with the balance of the light correctly diffused and distributed. Direct and reflected glare should be minimized. The lighting plan should take into account the low ceilings and small room proportions in residences as well as the fact that people at home are often closer to the light sources than they are at school or at work.

QUANTITY. There is no one answer to the question of the amount of illumination in the home, since there are so many variables involved. Research and experience have, nevertheless, resulted in the development of some recommendations for home lighting, listed in Table I.

These recommendations, reported by the Illuminating Engineering Society, are concerned with the lowest levels of illumination at which seeing is easy, accurate, and comfortable. These recommended numbers of footcandles can be achieved by any combination of general and supplementary lighting, but the general lighting should be not less than 20 footcandles and should contribute at least one-tenth of the total amount of illumination on the task.

It should be noted that maintenance conditions—depreciation of lamps and room surfaces, dust and grease collecting on lamps and reflecting surfaces, and the like—may require that higher levels of illumination be provided for any particular task in order for it to receive the amount of light indicated in Table I. Also, the age of the person performing the particular task makes a difference in light requirement; as we have seen, visual acuity is affected by age.

In making the recommendations, consideration has been given to costs and present-day lighting practices. The eyes can adjust to much more illumination than the levels recommended; it should be kept in mind that they are minimum and conservative.

BRIGHTNESS RATIO. Although the nearly uniform lighting of schools, offices, or commercial interiors is not necessary for the activities of the home, precautions should be taken to insure against sharp contrasts in brightness between the seeing task and its immediate surroundings. Optimum visual performance and comfort both suffer, also, where there is too much contrast between the task and the rest of the field of view.

When discussing these brightness ratios, we use footlamberts as the unit of measure. The footlambert, as defined on page 22, is the product of the footcandles of light received on a surface and the reflectance of the surface itself. Thus, all the physical factors involved in lighting a task are taken into account in setting some rules for brightness ratios.

Generally, the area adjacent to a visual task should be no brighter than the task, but not less than one-tenth as bright; for tasks of long duration or those requiring relatively high brightness, the adjacent area should not be less than one-third as bright. The general surroundings not immediately adjacent to the task can be anywhere from one-tenth as bright as the task to 10 times as bright. However, maximum brightness at either the high or the low end of this range should not

TABLE I Recommended Minimum Illumination for Specific Visual Tasks[a] in Homes

FOOTCANDLES	TASKS
	Kitchen activities
70	Sink
50	Stove and work surfaces
50	Laundry and ironing
	Reading music scores [b]
30	Simple scores
70	Advanced scores
	Reading, writing, studying
30	Books, magazines, newspapers
70	Handwriting, reproduction, poor copies
70	Desk work, study
	Sewing
200	Dark fabrics: fine detail, low-contrast thread
100	Prolonged periods: light to medium fabrics
	Occasional periods:
50	Light fabrics
30	Large stitches, coarse high-contrast thread
50	Shaving, make-up, grooming: on face at mirror locations
30	Table games

Source: Illuminating Engineering Society. **IES Lighting Handbook.** Third edition. New York: the Society, 1959. pp. 9-81-82.

[a]Brightness of task must be related to background brightness.

[b]When score is substandard size and notations are printed on the lines, 150 footcandles or more are needed.

be used over substantial areas or be adjacent to each other.

Room decoration must become a part of the lighting plan if we are to achieve these desirable ratios because the reflectance from large areas influences brightness. White or pale-tinted ceilings should range in reflectance from 60 to 85 percent; 70 percent or more is required for effective performance of indirect lighting methods. Walls should have a reflectance of 35 to 60 percent, although more than 50-percent reflectance creates problems when portable luminaires are placed close to walls or when extensive wall lighting is used. According to paint manufacturers, the public seems to prefer wall paints with about 45-percent reflectance.

A wide expanse or background of window or glass wall covered with fabric may range in reflectance from 45 to 85 percent, but side drapes or other limited areas of decorative design on light backgrounds should have no more than 15-45-percent reflectance. The reflectance range for floors is 15-35 percent, but 25-35 percent is preferred because many visual activities fall into the heads-down class, which brings the floor into the secondary cone of vision.

In kitchens, bathrooms, and utility rooms, where efficiency is a major consideration, the values at the high end of the reflectance range are recommended. Where no close visual tasks are performed, finish and reflectance are less important, but extreme differences in brightness may still be distracting and uncomfortable.

COLOR. Following the preferred reflectances does not mean that colors must be washed-out or uninteresting. It is true that pure colors of high saturation, except for yellow, have low reflectance and are therefore not advisable; but these colors are usually wanted only for accents in small objects and accessories. By keeping such large areas as walls, ceilings, floors, and extensive window treatments generally neutral in color, variation of the color scheme of a room is made easy and inexpensive.

When choosing colors for decorating a home, decisions should be made under lighting conditions as similar as possible to those of the house and of the room in which they will be used. Many a housewife has suffered sad disappointment as a result of choosing the paint color for her living-room wall under the daylight lighting at a store. After the redecorating is completed, she discovers that her freshly painted wall, seen in company with her rugs and drapes and by the evening lamplight of her living room, is not what she meant at all.

Colors in the home may now extend beyond those in paint and furnishings to those available in the light sources themselves. Although colored fluorescent lamps are still suitable only for purposes like outdoor Christmas decorations, tinted incandescent lamps now offer new possibilities for creating pleasant, color-brightened surroundings in leisure-living areas. They should not be used, however, for critical, prolonged, or demanding visual tasks, as color tinting lowers the initial brightness and efficacy of a light source.

FLEXIBILITY. One of the newer aids to flexibility in lighting in the home is the dimmer, a device that permits selection of the desired lighting level by simply turning a knob or pushing a button. Such units, although still expensive, are excellent, as are the more familiar three-way luminaires, which provide three different levels of illumination. These allow for quick increase in lighting for particular pursuits, but can be used when lighting for casual seeing is all that is required.

Flexibility is still most often supplied, however, by the use of some type of movable floor, table, or wall unit, which can supply extra light for specific visual tasks at key points like these:

1. On or near telephones
2. Next to easy chairs
3. On or beside desks or writing tables
4. At game tables
5. At each end of a long sofa
6. At the piano
7. Next to chairs and tables used for hand sewing
8. Next to sewing machines. Although many sewing machines have attached small lamps, additional lighting is needed and should be so adjusted that it does not cast shadows in front of the needle.
9. Above and on both sides of dressing table and bathroom mirrors. In the bathroom, shielded two-tube fluorescent units will distribute light better than large bulbs do.

10. In separate bathroom enclosures such as tub, shower, or toilet. Vaporproof units are required in shower enclosures.
11. In the laundry. Directional lighting at the ironing board will help show wrinkles. Daylight fluorescent tubes make it easier to see stains and scorches.
12. In the kitchen at stove, sink, and work surfaces
13. In the bedroom above or beside the bed.

TELEVISION LIGHTING. Home television viewing has become a major activity, in terms of time, especially among children. Lighting conditions during school television activities are carefully planned by experts; at home, however, the surroundings in which children watch television may not be lighted for maximum visual ease.

Correctly adjusted television tubes are considerably brighter than movie screens, so it is not necessary to have the room completely dark. In fact, lighting experts recommend that there be a low level of lighting throughout the room, in order to avoid an excessive brightness contrast to the television screen. However, no light should fall directly onto the screen or into the eyes of the viewer.

Again in order to minimize contrast, the wall behind the television set should be light, but not lighter than the screen. It is also helpful, for the same reason, if the set has light-colored surfaces immediately surrounding the screen.

OUTDOOR LIGHTING. Once primarily a matter of safety, outdoor lighting has become a part of the decorating scheme of the home as the trend toward "outdoor living" grows.

Lighting for close visual tasks is not usually needed outdoors. As a rule, the quantity of light used is largely a matter of taste, but the minimums recommended by the Illuminating Engineering Society range from one-half footcandle for general garden lighting up to 10 to 20 footcandles for emphasizing focal points of small area. These levels may be reduced to one-tenth under some conditions—for example, where there are no street lights or houses nearby.

For continued outdoor use, lighting equipment should be of some weatherable material; aluminum, brass, copper, or stainless steel are generally useful. Spotlights and floodlights may use colored bulbs, or the cover glass may be tinted. When colored light is of the same hue as the object lighted, the color of the object is heightened. Blue-green or blue-white tints enhance foliage. Cool colors supply an appearance of depth, and pale blue lighting can make a garden look moonlit. The familiar yellow "bug light" tends to deaden the appearance of grass and foliage.

Even low-wattage lamps, if poorly shielded, are offensive to the eye when seen outdoors at night; so, every effort must be made to protect the visual comfort of neighbors and passers-by, in addition to those on the scene. Shrubs and hedges can provide natural shielding for outdoor lighting equipment as well as daytime concealment.

A Lighting Check List

General lighting should be installed in accord with these basic rules:

1. All tubes or bulbs should be shielded from direct view.
2. Where interchangeable bulbs are possible, enough wattage should be used to obtain correct amount of light.
3. General lighting units should be arranged to distribute light throughout the room.
4. Units should be placed where they do not interfere with placement of tall furniture or with pictures.
5. Fluorescent tubes used for general lighting should be of the quick-start type.

At present, the ceiling luminaire is still the most commonly used type of general lighting. Here are some suggestions for successful use of this light source:

1. Units should have at least six feet, six inches clearance below them; if their height is adjustable, it should be possible to raise them to that height.
2. Indirect ceiling units should be used only where ceilings are high, as they must be hung well below the ceiling to spread light out on the ceiling. If

ceilings are low, use units with glass or plastic diffusing bowls that will provide a soft, pleasant light with minimum brightness toward the eyes of anyone seated or standing six feet away.

3. Built-in spotlights over the dining table add interest, but are inadequate without other general lighting in the room.
4. Single fluorescent tubes in ceiling units are adequate only for small utility rooms, halls, or other areas of less than 100 square feet. A good rule of thumb is that total wattage of fluorescent tubes should be not less than one-half the floor area in square feet.
5. Recessed ceiling units are suitable for low ceilings, but care should be taken that the unit is large enough for the space and that provision is made to avoid too much contrast with the surrounding ceiling. Other light should be directed toward the ceiling.

The portable lamp is not only the most used kind of household lighting equipment but also the one in which the individual probably has the greatest degree of choice. Therefore, it is important to keep in mind these desirable design factors when buying:

1. Tall lamps spread light better than short ones.
2. Lamp shades wider at the bottom than at the top spread light better than drum-shaped shades.
3. Lamp shades should be white or light in color, in order to reflect most of the light.
4. The shade should be dense enough to keep the bulb from being seen through it.
5. If walls are relatively dark, lamp shades should transmit less light, so as to avoid too much contrast with walls. (In general, however, walls should not be dark.)
6. Lamp shades open at the top add to the general lighting, but, unless the bulb is low enough not to be seen, they may need louvers or a shield arrangement.
7. Diffusing bowls or discs in glass or plastic beneath the bulbs soften the lighting, but they should not be so dense that most of the light is sent upward.
8. Dressing-table lamps, which need no diffusing bowls, should have shades of white or pale pink to avoid distorting colors.

Even a well-designed lamp may do no good if it is not properly placed. But, by careful positioning, one lamp may be used to serve more than one task.

In all cases, lamps should be placed to throw shadowless light on the work space. If the lamp is within view of the person at work, the bottom edge of the shadow should be just below eye level. For writing, a right-handed person will want the light coming from the left, but a left-handed person will want it coming from the right.

If lamps without diffusing bowls cannot be avoided, their harmful effects may be reduced by placing a mirror or a piece of glossy paper over the work or reading matter and moving the lamp around until the reflection of the bulb cannot be seen. In this way, the discomfort from reflected glare is avoided.

Bullet-shaped lamps, which are popular and inexpensive, are, unfortunately, not recommended for any task except sewing. Their high brightness, dense shadows, and poor diffusion make them undesirable as light sources.

SAFETY. Correct lighting can perform a major service in reducing the appallingly large number of household accidents occuring every year.

Safe lighting in the home requires that there be a light at the top and the bottom of every stairway, with three-way switch control on both floors. This precaution should not be neglected on the short stairways of split-level houses or in the attic or cellar. The switch at the top of the cellar stairs and the one at the bottom of the attic stairs should control the nearest general lighting unit as well as the stair lights themselves. Wall switches in passageways and near the principal doorway of each room should light one or more lighting units or lamps. Where there are one or two steps between rooms, a recessed step-light at one or both sides may be used if overhead lighting is not feasible.

In order to avoid accidents, lighting in the kitchen, laundry, workshop, garage, or any other place where there is equipment with moving parts should be controlled by a switch. So that nobody will be tempted to touch a pull chain with wet hands, all lighting in the bathroom should be controlled by a switch.

A pull chain is permissible, if it can be reached easily from the doorway and if the cord ends in a luminous attachment, in storage areas and closets. Every closet over nine square feet in area needs a light inside.

In completely dark bedrooms, a person getting up at night should be able to switch on a light before getting out of bed.

Night lights of three and one-half to seven and one-half watts should be used in bathrooms, hallways, and bedrooms, at the top of stairs, and at any other location that might prove a hazard to a sleepy person. An inexpensive night light, complete with shield for the bulb, that can be plugged directly into outlets is widely available.

Lighting should be available at every outside entrance, on covered porches, above or beside steps, and at the garage door. Outdoor lighting should be controlled from within the house, with the garage lighting controlled from both the garage and the house. Flood lamps mounted under the eaves provide protective lighting between house and garage and for the yard. A lighted house number is helpful.

Wiring

Not only should the wiring in a home be adequate for its electrical requirements, but new homes should also be wired to meet general future requirements. Any family is likely to adopt new uses for electricity, and there should be extra terminals in the fuse box to allow additional circuits to be installed as needed.

The original circuits should be distributed so that the family will not find itself unable to use a toaster in the dining room when an electric iron is in use in the kitchen—or any such routine simultaneous use of appliances. Stoves, water heaters, dishwashers, and some television sets and air-conditioning units require special circuits and heavy wiring.

In order to keep home lighting schemes flexible, outlets should be distributed so that a minimum of one double outlet for each 12 feet of wall is available; outlets should also be placed so that they are not likely to be behind heavy pieces of furniture. In halls, there should be a convenience outlet every 15 feet for lamps and occasional appliances, such as the vacuum cleaner.

Several outlets are needed in the kitchen for various appliances. These outlets may be in the wall behind work spaces or built into the undersides of wall cabinets. In the bathroom, an outlet should be available for an electric razor and for a night light. Outlets on the necessary heavy-wiring circuits should be planned for appropriate points in the area where laundry is done. Outside the house, there should be weatherproof outlets for every 15 feet of terrace or covered porch.

Do-it-yourself wiring or homemade additions to an existent wiring system should be checked by authorities to be sure they conform to safety regulations and local building codes. Minimum wiring capacities designed primarily for safety are set forth by the National Electric Code, available from the National Fire Protection Association, 60 Batterymarch Street, Boston, Massachusetts.

In the average household the following wiring safety precautions should be observed:

1. Wires should not be run under carpeting.
2. Extension cords and other extended wiring should be fastened to baseboards with special clips or insulated tacks designed for the purpose.
3. Wires on electrical equipment should be checked periodically for fraying or cracking of the insulating wrapper.
4. Open wall sockets should be protected with special devices or adequately blocked off to prohibit exploration by small children.
5. All electric cords should be sturdy and well insulated.
6. For reasons of safety, it is economically poor as well as hazardous to buy cheaply made electrical equipment of dubious manufacture.

LIGHT IN THE SCHOOL

A growing understanding of the principles of good lighting and good seeing, combined with awareness of the importance of developing and preserving the visual skills of children as an aid to the vital educational process, have led to wiser planning of illumination in new school buildings and, often, to the improvement of lighting in older buildings.

Lighting satisfactory for school use must be ample in amount for the visual task, glare-free, well diffused, well distributed, steady, and of a color composition both pleasant and tailored to a particular purpose.

For the school situation, with its constant shifting of types of visual demands, lighting arrangements must always be flexible. Since pupils no longer spend their school days sitting still in seats rooted to the floor, there is no fixed viewing angle; illumination in the classroom should be sufficient for the pupil to work comfortably while facing in any direction. Teachers usually alternate heads-up and heads-down tasks; this, also, should be taken into account in planning lighting.

The visual capacities of school children can vary widely, from those of first-graders to those of mature high-school students, and from students with normal vision to those with partial vision. A few pupils can read and work under lighting conditions below standard levels without suffering difficulties. It is not this group, however, which should set the standard: no harm is done to those who are receiving more or better illumination than they need, but pupils and teachers who attempt daily work in surroundings lighted inadequately for them may suffer fatigue and impaired efficiency. Thus, lighting levels should be planned for the benefit of all those who share in the school surroundings, rather than for a statistical average.

The Visual Task

Reading, writing, and study of visual-aid materials constitute the main visual tasks in the school scene.

READING. Reading enters into every subject in school, and it is highly important that this task be accomplished with no unnecessary amount of effort or sense of strain. Reading involves, also, materials varying widely in intrinsic visual problems: handwriting or printing duplicated by various means and ranging in content from simple words to numerals and arithmetic symbols. Even with the best lighting, other standards must be met for maximum visual efficiency in reading.

Reading pencilled handwriting is one of the most difficult seeing tasks in the classroom and therefore requires the highest illumination levels. Since good contrast between the writing and the background helps to reduce the problem, care should be taken to provide pencils that make a dark line, although they should not be so soft as to smear. Paper used for pencil writing should be white or slightly off-white.

Reading duplicated material is another task in which every effort should be made to provide the best visual contrast possible. Spirit-duplicated worksheets and assignments, widely used for classroom work because the process is inexpensive, are often difficult to read because of their purple or blue letters. The masters for spirit duplication and mimeographed and multilithed material should be of high quality and carefully prepared for high contrast between the typed characters and white background paper.

Arranging for ease of reading from chalkboards presents many special problems in the classroom. Since in elementary school, the student may be as far as 30 feet from the board, it is necessary that the writing have a high degree of visibility. Blackboards, which furnish a good contrast to white chalk, are easy to read, especially if the illumination is low; but their sharp contrast with the surrounding walls creates other visual problems. (These will be discussed in more detail later in this chapter. See p. 38.) Medium green boards which contrast less with the walls are preferred in many schools; but, unless they are well lighted, the contrast between board and chalk is often too low for easy reading, especially at a distance.

Most books recently designed for school use are satisfactory in their consideration of visual problems. Printed matter in general has good contrast when the characters are

printed in black, nonglossy inks on white or off-white paper. For clear print and good visibility, books should be printed on good-quality paper—opaque, nonglossy, white or off-white, and having a high diffuse reflectance.

Consideration should be given, also, to the design of type used in reading materials for students. Some type faces are clearer than others of the same size. Within limits, slightly bolder type is more desirable, especially for young children. Books for children with partial vision should be printed in 24-point type for the elementary school and 18-point type for the junior or senior high school. Even with excellent lighting available, it is not recommended that these children read smaller sizes of type; it is better to assign fellow pupils with normal sight to read aloud to them.

Table II shows recommended sizes of type for pupils of different ages and with normal vision. The information in column 2 of the table is printed in the size of type recommended for each age group.

TABLE II | **Type Sizes for Pupils of Different Ages**

AGE	TYPE SIZE (IN POINTS)
Under 7	24 or larger
7-8	18
8-9	14
9-12	Gradual decrease to 10

Source: Winifred Hathaway. **The Education and Health of the Partially Seeing Child.** Third edition. New York: Columbia University Press, 1954. p. 107. (Adapted)

Most comic books are properly objected to as reading material for children because of poor visual characteristics. The paper is usually of such quality and color that contrast is much reduced and the letters are fuzzy or blurred. The lettering, largely done by hand, is often about equal to 6-point type; this size, far too small for young children and too small even for prolonged adult reading, is used in listing names in large-city telephone directories.

WRITING. Mat white paper is the most desirable for writing use, but any paper having the same qualities as those prescribed for good contrast in reading will suffice.

Pencils should be kept sharpened, and only good ink, which writes a clear, dark line, should be used. Watery, poor-quality ink—sometimes mistakenly used in the name of economy—lays an undue strain on the eyes. Washable inks—certainly a practical precaution with youngsters—which still fulfill the requirements of good visibility are widely available.

For both reading and writing, desks and chairs should be of the correct height to insure a comfortable working posture. Desk tops that can be tilted to hold books in a good reading position are desirable; if these are lacking, the children's books can be leaned against bookrests or propped up against other books, at a distance of about 14 inches from the eyes.

Teachers should encourage all children engaged in close visual tasks to develop the habit of looking away from the task briefly at convenient periodic intervals, a practice which helps prevent eye fatigue.

VISUAL AIDS. With visual aids becoming increasingly important and more widely used in the teaching process, there is need for increased concern to insure that they meet high standards of visibility. There is no learning advantage to pupils if they are required to peer at maps, pictures, or charts with too-small or indistinct lettering or faded, washed-out colors. Filmstrips, slides, and motion pictures should be sharp, clear prints. Projectors should be adapted to the size of the room so as to provide a distinct image for each pupil.

For further recommendations on suitable visual conditions for television, see page 30.

Daylight in the Classroom

ARCHITECTURE. At one time, the recommendations for classroom design called for windows on the left side of the row of pupils' desks, with no other windows in the room. It became apparent that this resulted in darker areas on the opposite side of the room. Since the side of the room opposite the

window receives most of its light from the window area closest to the ceiling, the problem has been, in part, corrected by building schools with larger windows extending as close as possible to the ceiling. In one-story school buildings, clerestory lighting, skylights, and light-directing panels have been employed.

Opinion on effectiveness and economy of daylighting of schoolrooms by means of architectural design covers a wide range. At one extreme is the contention that a well-designed daylighting system can provide adequate classroom illumination under all but the severest conditions of loss of light intensity due to darkened skies. At the other extreme is the claim that construction and maintenance costs may be materially reduced by providing for all of the ordinary classroom light demands from electrical sources, and by supplying only a small amount of window space. The controlling factor in finding an answer to the question is the situation of the particular school, its particular classroom, and its particular pupils.

For example, where snow-covered ground outside the classroom window is very common, reflected light from this source will provide a well-illuminated room, even on dark days; in this case, a considerable amount of money may be saved by the use of reflected daylight rather than artificial light. On the other hand, if the school is in a climate of bright sunshine, but one where keeping classroom temperatures from soaring too high for comfortable learning is an important problem, a balance must be struck between the cost savings of daylight and the extra burden on heat control or on air-conditioning costs. In both cases, of course, the cost of devices for controlling excess brightness must be taken into account.

In designing a new school—or in renovating an older one—the question of how to admit beneficial elements without at the same time admitting too many harmful elements should be weighed carefully and by people with special knowledge. Under the coordination of a capable architect, some of the people with technical knowledge who should be involved in planning school lighting are these: structural, heating, ventilating, and acoustical engineers; electrical and/or illuminating engineer; architectural designer; color consultant; and landscape architect.

Given the location, climate, and other factors peculiar to your community, which of the following three types of installations is most suitable for your school?

1. Major emphasis on natural light from outdoors, with electric lighting for help on days when natural light is insufficient
2. Major emphasis on artificial lighting with daylight as a supplement.
3. Lighting entirely independent of daylight, with windows provided solely for the purpose of looking out.

Unless the decision is to exclude daylight entirely, some architectural features to control natural light will be necessary. The trend in newer schools is toward using exterior projections, louvers, baffles, and metal-shade screening to cut off view of the sky and direct light downward. One method being advocated for new schools is the use of low-transmission glass (10 to 20 percent) for the lower part of a window; the upper part is clear glass, shielded from skylight and sunlight by outside overhangs. In this arrangement, ground light passes through the clear upper part of the window to light the ceiling, which helps to light the room.

CONTROLLING LIGHT. In addition to these and other methods of exterior light control, the entrance of daylight into the classroom must be controlled by one or more ways of diffusing light from the window areas. In older schools with no funds for remodeling, window treatment may be the only means of control of daylight feasible at any given time. In addition to light control for ordinary work, means must also be provided for cutting off light to the degree recommended for some audiovisual aids.

Perhaps the most satisfying type of interior window treatment for the classroom is an opaque, fire-resistant plastic drape. When mounted on tracks installed a foot or more out from the windows, a free flow of air is permitted without excessive light leakage.

When roller shades are used they should be attached either to the middle of the window with one roller directed upward and the other downward or to the bottoms of their respective sashes and directed upward. If both are attached at the middle of the window, the space between the rollers should be shielded to admit no light. Roller shades

should be light in color and admit and diffuse light, but they must be wide enough to prevent entrance of direct sunlight at the edges of the windows.

Venetian blinds should be mounted above the top of the window so that they will not block light at the top of the window when they are rolled up. They should be light in color, to reflect light to the ceiling and upper walls of the room.

Diffusing screens made of fiber glass may be mounted in the center of the window and arranged to shield the upper part. If hung at an angle of 45 degrees from the vertical, they cut down glare and diffuse light and still transmit about 60 percent of the light falling upon them.

Electric Light in the Classroom

Usually, whether a new school is being built or an old one remodeled, a lighting engineer should be asked to design the entire lighting installation. In this way, lighting may be tailored to the special needs of the school. In general, however, the *American Standard Guide for School Lighting* sets over-all standards, and determinations as to quantity of illumination may be made on the basis of recommendations resulting from studies in the field (see p. 52).

The standard cool white fluorescent lamp, which gives good color rendition and blends with daylight, may be used to give a cool feeling in the classroom. The warm white fluorescent lamp, closer in appearance to the incandescent bulb and about 4 percent more efficient than the cool white fluorescent, may be used to achieve a warm-feeling atmosphere. Whatever the choice of lighting type, however, the units themselves should be light-colored or translucent, in order to avoid a dark spot on the ceiling. All bulbs or tubes should be shielded from direct view below 95 degrees with the line of sight. For lighting flexibility, switches should be available to control each row of units.

Quantity of Light

Improvements in and variety of lighting units make it possible to have nearly any level of illumination desired at any point, whether from natural or electric light or a combination of the two. Existing light should always be measured by a light meter before planning changes, and lighting schemes should be checked with the meter from time to time while in operation. Instructions in the use of this device appear in this manual on page 22.

Whether the emphasis on lighting the school in general is on natural or electric light, research seems to indicate that lighting is best controlled electrically during activities involving projected material. It is then possible to achieve a low-level lighting that may result when projected pictures are viewed for a long time in an excessively darkened room. Lighting during the use of films and filmstrips may amount to as much as one footcandle. This much light, directed downward on desks in a normal-sized classroom, will not be too much for good picture-viewing and yet will make it possible for the class to take notes. With lighting units in the ceiling at the side of the room opposite the screen and installed in such a manner that the light is directed downward and away from the screen, great flexibility may be obtained by simply varying the wattage of bulbs in the fixtures.

Table III shows the *minimum* number of footcandles recommended for lighting some specific classroom tasks at any time. On tasks involving discrimination of fine detail for long periods of time under conditions of poor contrast, specialized supplementary lighting is considered necessary. As with general lighting, care must be taken that the specialized lighting does not produce direct and reflected glare or objectionable shadows and

TABLE III Recommended Minimum Illumination for Specific Visual Tasks in Classrooms

MINIMUM FOOTCANDLES ON TASKS	TASKS
30	Reading printed material
70	Reading pencil writing
	Reading spirit-duplicated material
30	Good
100	Poor
100 *	Drafting, benchwork
150 *	Lip reading, chalkboards, sewing

Source: Illuminating Engineering Handbook. **IES Lighting Handbook.** Third edition. New York: the Society, 1959. p. 9-82.

*Combined general and specialized supplementary lighting.

TABLE IV | Recommended Illumination for Specific School Areas

MINIMUM FOOTCANDLES ON TASKS	AREAS
	Auditoriums (See also Theaters.)
15	Assembly only
30	Exhibitions
5	Social activities
70	Used as study hall
	Cafeterias
30	Dining area
50	Cashier
70	Food displays
	Kitchen
70	Inspection, checking, pricing
30	Other areas
	Classrooms
70	Art rooms
100 [a]	Drafting rooms
	Home economics rooms
150 [a]	Sewing
50	Cooking
50	Ironing
70	Sink activities
70	Note-taking areas
100	Laboratories
	Lecture rooms
70	Audience area
150 [a]	Demonstration area
	Music rooms
30	Simple scores
70 [b]	Advanced scores
100 [a]	Shops
150 [a]	Sight-saving rooms
70	Study halls
70	Typing
20	Corridors and stairways
	Dormitories
10	General
30	Reading books, magazines, newspapers
70	Study desk
	First aid rooms
50	General
100	Examining table
	Gymnasiums
30	Exhibitions, matches
20	General exercising and recreation
5	Dances
20	Lockers and shower rooms
	Badminton
30	Tournament
20	Club
10	Recreational
	Basketball
50	College and professional
30	College intramural and high school with spectators
20	College intramural and high school without spectators
	Volley ball
20	Tournament
10	Recreational
	Libraries
	Reading rooms
60	Study and notes
30	Ordinary reading
30	Stacks
50	Book repair and binding
70	Cataloging
70	Card files
70	Check-in and check-out desks
	Lounges
10	General
30	Reading books, magazines, newspapers
	Offices
150	Accounting, auditing, tabulating, bookkeeping, business machine operation, reading poor reproduction
100	Regular office work, reading good reproductions, reading or transcribing handwriting in hard pencil or on poor paper, active filing, indexing references, mail sorting
70	Reading or transcribing handwriting in ink or medium pencil on good quality paper, intermittent filing
30	Reading high-contrast or well-printed material, tasks and areas not involving critical or prolonged seeing, such as conferring, interviewing, and inactive filing
	Storerooms
5	Inactive
	Active
10	Rough bulky
20	Medium
50	Fine
	Swimming pools
10 [c]	General and overhead
	Underwater
	Theaters
5	During intermission
0.1	During motion picture
30	Toilets and washrooms

Source: Illuminating Engineering Society. **IES Lighting Handbook.** Third edition. New York: the Society, 1959. pp. **9**–76-84.

[a] Combined general lighting and specialized supplementary lighting.

[b] When score is substandard size and notations are printed on the lines, a level of 150 footcandles or more is needed.

[c] 100 lamp lumens per square foot of pool surface.

that the light source is adequately shielded for eye protection.

In Table IV, recommendations are made for lighting levels in specific areas of the school building. Here, too, it should be kept in mind that these are minimum levels; in instances where supplementary lighting is recommended, the precautions mentioned in the paragraph above must also be taken into account.

Brightness Ratios

Arranging for limited differences in brightness between the visual task and the surrounding areas is as important as having enough light on the task itself. Marked differences continue to cause temporary losses in ability to see. Table V recommends limits of brightness ratios in schoolrooms. The ratios in Table V are recommended as maximums; reductions are generally beneficial.

TABLE V | **Recommended Limits of Brightness Ratios for Classrooms**

RATIO	TASKS
1 to 1/3	Between task and its adjacent surroundings
1 to 1/3	Between task and more remote darker significant surfaces
1 to 10	Between task and more remote lighter significant surfaces *
20 to 1	Between luminaires or window and surfaces adjacent to them
40 to 1	Anywhere within the normal field of view

Source: Illuminating Engineering Society, American Institute of Architects, and the National Council on Schoolhouse Construction. **American Standard Guide for School Lighting.** (ASA-A-23). New York: the Society, 1962. 40 pp.

* At 30 footcandles. As levels of illumination increase, brightness ratio should be decreased.

Room and Equipment Reflectances

Correct reflectance values in a classroom are most helpful in achieving the desirable ratios of brightness. In this regard, there are a number of considerations. (See Fig. 13.)

FURNITURE surfaces should have a reflectance of 25 to 40 percent, although the sides of furniture may be slightly darker. Desk tops of light-finished birch or maple, or nonglossy laminated plastics fall within this desirable range of reflectance. Desks with dark finishes can be sanded down to the natural wood and refinished with nonglossy varnish or lacquer or resurfaced with laminated plastic. Desk tops should be nonglossy so as not to reflect light from electric sources or windows. Other furniture in the room, such as bookcases or cupboards, should not be glossy; if they have glass doors, the glass should be sandblasted to have a rough surface or be replaced by dull-finished, unbreakable plastics or wood.

FLOORS should have a reflectance of up to 50 percent and should be as light as is practically possible, since they are, after desks, the secondary background for heads-down tasks. Wood floors should be left their natural light color and the surfaces sealed with clear varnish followed by nongloss wax. They should not be oiled, since this darkens them. Light-colored tile materials may also be used and, again, protected with nongloss wax.

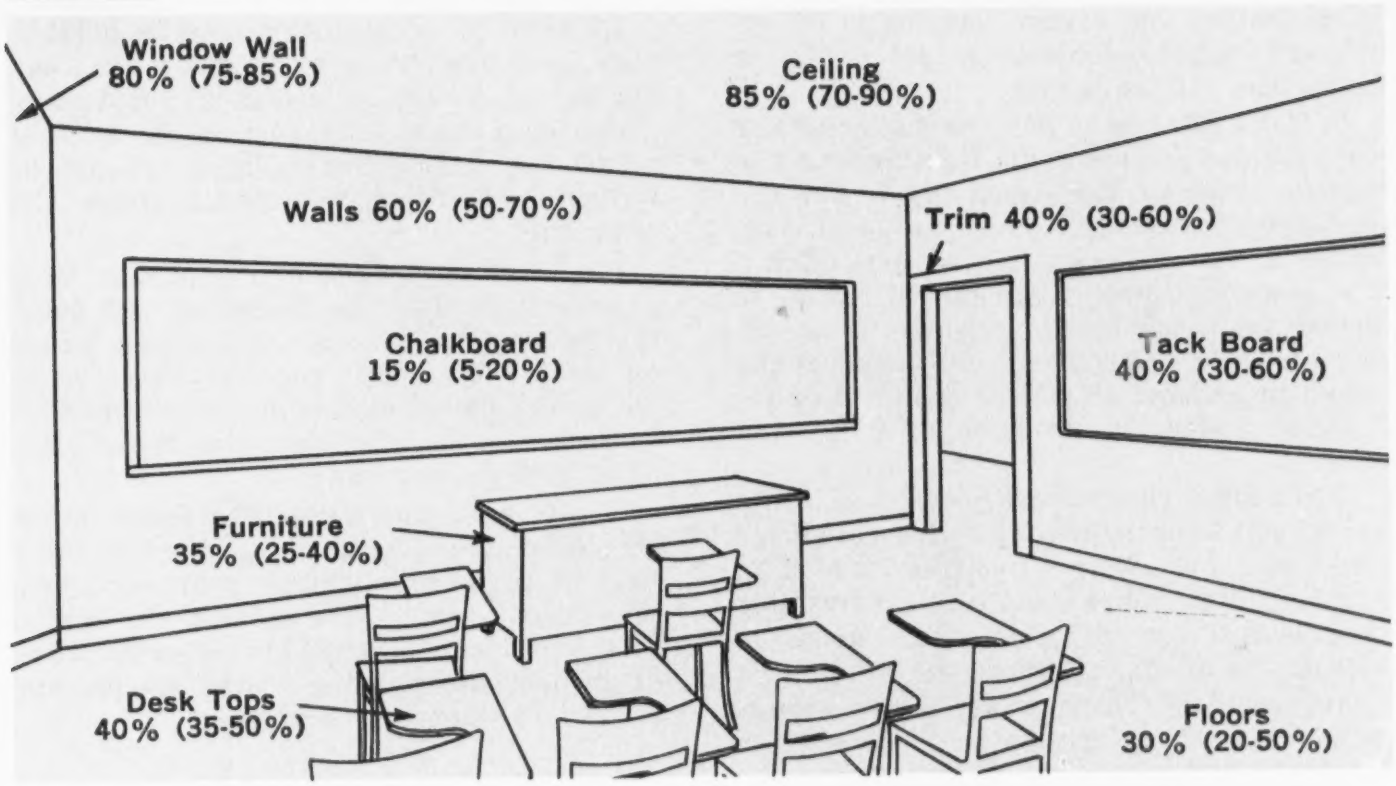
WALLS should have a reflectance of 50 to 70 percent. This range is adequate to reflect light back into the room efficiently and still be dark enough for appropriate balance with the average school visual task. This also allows a wide range of attractive colors. A wall before which an instructor usually stands should have a reflectance in the lower end of the 50-70-percent range. Walls with windows in them should have a reflectance of more than the 50-70-percent range, to lessen the brightness differences between the windows and adjacent surfaces.

CEILINGS should have a reflectance of as high as 90 percent, providing maximum aid to indirect lighting and reducing brightness differences between ceiling luminaires and other types of lighting fixtures. Ceilings should be white or slightly off-white and have a nonglossy or flat finish, especially where indirect lighting is use. In using acoustical ceiling materials, it must be remembered that these surfaces, usually perforated or patterned in some way, will reflect less light than a smooth surface of the same color.

CHALKBOARDS involve a twofold reflectance problem. They must be light enough to blend well with the rest of the background. They must also be dark enough to provide sufficient contrast to chalk writing so it can be easily read.

Under typical use conditions, blackboards should have a 5-10-percent reflectance. To reduce the high contrast to the surrounding

FIG. 13 Recommended Classroom Brightness Ratios



walls, it is helpful to cover them, perhaps by maps or shades, when they are not in use. Where they are used frequently, localized lighting bringing the total up to 150 footcandles will reduce the brightness difference. In many classrooms, where blackboards are rarely used, they could be replaced by neutral-tinted tack boards or, for maximum flexibility, by reversible boards, one side of which is blackboard, the other side tack board.

Chalkboards, also available in a medium green color, should have a reflectance of from 5 to 20 percent.

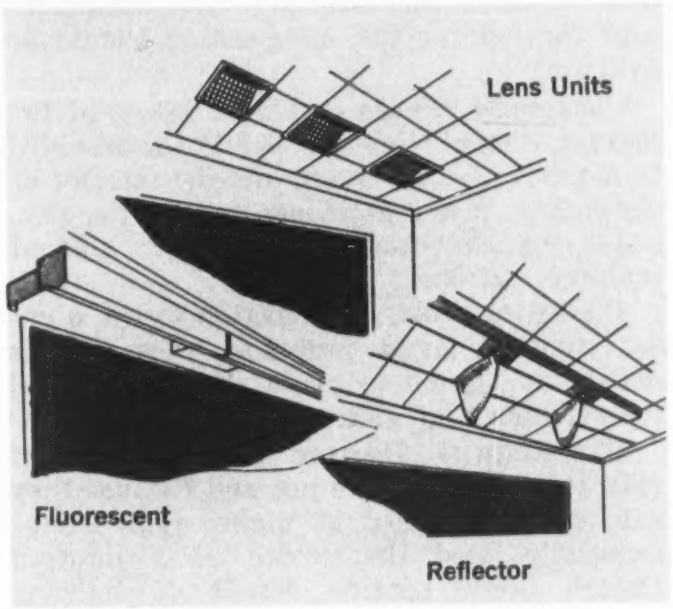
Supplementary local lighting, well planned, not only helps in solving the problem of high wall-chalkboard brightness difference but also improves visibility of chalk on black or colored boards. (See Fig. 14.)

One further caution: All types of chalkboards should be easy to clean and cleaned often.

COLOR. The educational environment should be attractive and interesting as well as healthful. The interests and activities of the pupils and the geographical location of the school and of each room should be taken into account in selecting color schemes. Blues and greens suggest coolness and are restful and pleasant; in cold climates or rooms with north light, yellows and pinks seem warmer and more appealing.

The trend today is to use different colors in different rooms as well as within the same room where various colors are combined harmoniously with one another or with grays of desirable reflectance. Accents may also be used, as in home decoration, to offer interest

FIG. 14 Recommended Types of Supplementary Chalkboard Lighting



and variety for the eye. Such accents should be small ones and wisely chosen. Nearly all of the advice and caution applicable to use of color in home-decorating (see p. 29) is useful also for the school.

In Table IV (see p. 37), recommendations are provided for minimum lighting levels in various areas of the school plant. For the guidance of school personnel, the brief comments in the following paragraphs offer a few hints for lighting specialized rooms. It should be remembered, however, that the lighting of these classrooms, like that of the school in general, should be designed or remodeled under the direction of a lighting expert.

ART ROOMS. The improved-color, cool, white fluorescent lamp is helpful in accurate color rendition. For work involving modeling, overhead spot lamps are useful. Adjustable desk lamps are advisable where glaze or texture are of importance in the work.

AUDITORIUMS. The lighting, largely atmospheric, should be arranged to provide for safety in aisles and on steps and for the practical uses of a theater audience. Facilities for stage lighting should be available for use during performances.

CAFETERIAS. Improved-color fluorescent lamps should be used so that there is no distortion of the colors of food. Incandescent light may be used over the serving areas to enhance eye appeal and aid in speedier service. Lighting arrangements to aid in cleanliness and safety should be observed as in home kitchens (see p. 29). If the cafeteria is used for study purposes, additional light sufficent for reading and note-taking should be available.

CORRIDORS. Where corridors are used for lockers, enough lighting should be provided to make it possible to see into the interior of the locker. It is a good idea to provide, also, some supplementary lighting for student monitor stations.

DRAFTING ROOMS. In addition to the highest lighting levels practical, these rooms should be lighted to avoid shadows around instruments and glossy reflections.

GYMNASIUMS. Because of the variety of uses to which they are put and because they are sometimes used at night, gymnasiums especially need the advice of a lighting expert. Some specific details of lighting gymnasium activities are listed in the *IES Lighting Handbook*. (See p. 52.)

LECTURE ROOMS. Lighting must be flexible, with levels high enough for general use and low enough for correct use of projected materials. Supplemental lighting on the lecturer or on the demonstration areas should be within a 40-60-degree angle above the horizontal.

LIBRARIES. School libraries require no more general light than the classroom, but bookshelves need special units that can be turned on and off for ease in reading titles. Chairs and tables should be capable of arrangement so that no reader need face a source of glare or read in his own shadow.

SHOPS AND LABORATORIES. These areas should be lighted according to the best practices of industrial lighting, with additional precautions taking into account the special safety problems aroused by the combination of inexperience, youthful high spirits, and potentially dangerous equipment.

Maintenance

Even foresight and expert planning of a school's lighting system will not guarantee good lighting permanently; without adequate maintenance, equally well planned, the lighting system can be robbed of as much as 50 percent of its effectiveness by a combination of these three factors:

1. Dirt on room surfaces
2. Dirt of lamps and luminaires
3. Depreciation in light output from units.

Not only is a planned maintenance program for the school more efficient than a haphazard one but it is also more economical. Since modern school lighting systems are more complex than the old-fashioned facilities, school systems often have regular lighting maintenance arrangements to provide consistent service. If this is not possible, there are lighting maintenance companies which offer such services on a contract basis. School administrators should plan, using whatever maintenance or custodial services are available to them, a schedule for cleaning of luminaires and room surfaces, for repainting, and for replacement of lighting equipment parts. Classroom teachers should

cooperate by reporting promptly any conditions in their rooms requiring attention.

How often the cleaning and painting should be done depends largely on the location of the school, the amount of dirt and grime in the air, and the design of the lighting unit. The easiest and most efficient way to determine how often complete cleaning should be done is to survey the school periodically with a light meter, to determine how much illumination and brightness ratios have been affected by dust and soot. A film of dirt on luminaires, windows, walls, and ceilings can rob a room of illumination before it even begins to look dirty.

Lighting units should be cleaned periodically. Tests show that they should be washed rather than wiped for greater efficacy. Louvers or baffles used to shield fluorescent tubes should be washed, just as glass reflectors or bowls are washed. Luminaires that are easy to handle should be used. Windows should be washed at least twice during the school year.

The light output of all lamps decreases throughout the life of the lamp, the life expectancy varying with the type of bulb or tube and its size. The life range of an incandescent bulb of the sizes used in schools is from about 750 to 1000 hours. After about 1000 hours, they may be so darkened that, although still giving light, their output is drastically reduced.

Fluorescent tubes, on the other hand, sustain their quickest loss in light output early in their life, during the first 100 hours of operation. Light loss is much less after that point. It is the average output after the initial loss that should be computed in judging the lighting maintenance of the luminaire.

Dealers can provide data for each type of fluorescent tube. The usual hot-cathode fluorescent tubes have a longer life if they are not turned on and off frequently. The coating of the cathodes, which is used up during the life of the tubes, deteriorates more rapidly during starting, thus causing a shorter life expectancy. If the usual period of operation is three or four hours, the tubes should last about 7500 hours under good operating conditions. Rapid- and instant-start tubes are free from starting troubles.

On the other hand, cold-cathode fluorescent tubes with less light output per watt are not affected by the number of times they are turned on and off. Their life is rated at 15,000 or 25,000 hours, depending on lamp type; but, as with all light sources, the light output decreases continuously throughout life. After very long use, it is wise, therefore, to examine the depreciated light output to see if the light is still being produced economically.

An efficient way of maintaining the proper output of the lamps recommended for some lighting systems is by group replacement. Under this plan, there is periodic replacement of all or a certain specified number of lamps, rather than of individual lamps as they burn out. The time of replacement is usually at about the 60- or 70-percent point in the lamp's life—that is, just before the time that burnouts begin to become frequent.

Teachers can aid in the maintenance of the lighting system by keeping in mind that factors other than electrical equipment are involved: a broken window shade, for example, may be doing more harm to the over-all lighting scheme in the classroom than a burned-out light bulb.

TEACHING ABOUT LIGHT AND SIGHT

The primary purpose of teaching about light and sight is to promote one of the most vital aspects of man's physical and mental welfare, good vision. Everyone should know not only the importance of eye care and of good lighting for visual tasks but also how to achieve it. Everyone should acquire the habit of arranging good lighting for close work.

Further, a person who has a sound grasp of essential requirements for healthful, safe, and efficient lighting will increase his effectiveness in the home and in his citizenship activities. Good lighting is needed not only in schools but in other public buildings, recreational areas, and streets. An informed voter and citizen will be able to make his decisions in terms of facts.

This manual does not propose a separate course on light and sight, nor does it suggest how much time should be devoted to problems in this field. Rather, it seeks to be a guide for classroom teachers in determining where they can introduce the essential facts into their teaching most effectively.

General Objectives and Activities

This section presents suggestions for a number of areas from the very first years of elementary school through high school. Throughout the entire school life of a child, there is both opportunity for and value in teaching about light and sight.

In the first years of elementary school, pupils need to develop intelligent habits in relation to reading, writing, and other close visual tasks. Children can learn at an early age that, although they often cannot change *what* they are looking at, they can change the *way* they look at it. They should acquire an understanding of what good lighting is, know how to get it when they need it, and realize that having it makes work less tiring. They should learn that correct working posture helps their vision and that satisfactory seeing conditions make it easier to maintain correct posture.

Learning to hold books and other materials at the correct angle and distance from the eyes is essential. They should learn, also, to keep their fingers away from their eyes, to eat healthful varieties of food, and to remember routine precautions against disease. They should be warned against staring directly at the sun or at brilliant, unshaded light bulbs.

Later in the elementary school, as early as grade 4, the teacher may offer systematic study of the care of the eyes, the symptoms of eye fatigue and of vision defects, and means of preventing some diseases of the eyes. An introductory study of the structure and function of the eye may also be an acceptable part of the program of health education in elementary schools.

Students can learn about light sources, something of the behavior of light, and how it is controlled to make the best use of it for various tasks. Such instruction might well include the simpler methods of measuring light and of judging whether a given room is well or badly lighted. Applications of correct lighting principles, particularly in the home, should be studied.

This subject should provide an excellent instance of cooperation between the home and the school, and sometimes of the extension of education beyond the school, if the teacher's approach is thoughtful and constructive. If the student simply goes home and announces to his parents that lighting arrangements at home are all wrong, parents are likely to become irritated and the child is unlikely to derive any experience of lasting usefulness. No environment is perfect, in terms of lighting or in any other terms; what the pupil should carry away from instruction in light and sight is the information that will enable him to adjust his environment as closely as he can to his immediate visual requirement.

If the material is taught in these relativistic, rather than absolute, terms, and with emphasis on flexibility and practicality, there will be very few homes that cannot derive

benefit from education in this field. Good lighting can be bought for very little money, but even small expense will not encourage its acquisition if the impression is left that no arrangement will do except the most modern and streamlined.

In the secondary school, science teachers can teach those aspects of light and sight that fit naturally into the work of particular courses. The study of seeing touches on such fields as biology and physics. Problems of light and sight fit readily into several other courses, especially health education and home economics. In addition, aspects of seeing can be taught in social studies, art, and shop courses. Materials for mathematics problems occur in such areas as measurement of lighting. Because of the high degree of departmentalization in the secondary school and because many students do not take certain courses which would touch upon light and sight, it might be best for systematic attention to be given to the whole subject in the general science course. In fact, when the required work in health education is brief, it is desirable that facts and principles on the subject of light and sight receive attention in many courses.

If the subject is to be taught through different courses, it is recommended that some effort be made to unify the program. This working out of details might be made by a curriculum committee or by the curriculum supervisor. These efforts would seek to avoid unnecessary duplication as well as the neglect of essential elements.

Suggested Curriculum Topics

The topics listed here for various courses do not offer a complete or final outline. Both teachers and children will think of other topics. The allotment of topics to subject fields should be changed to suit local needs and interests. Although this outline is meant primarily for secondary-school use, many of the topics listed under general science could be taught as early as the upper elementary-school grades. High-school courses will usually cover the field of light and sight as a whole, especially when the field is among those required of all students. At all levels, the subject needs to be studied partly through the use of models, exhibits, experiments, and lifelike situations, to avoid an entirely verbal, expository program.

GENERAL SCIENCE

I. Sight
   - A. Process of seeing
   - B. Structure and function of the eye
   - C. Defects of sight
   - D. Discovery and prevention of vision difficulties
     1. Hygiene and general health measures
     2. Safety and accident prevention
     3. Medical examinations and vision tests

II. Light
   - A. Physics of light
   - B. History of discoveries
   - C. Factors in seeing
   - D. Reflection
   - E. Refraction
   - F. Color phenomena
   - G. Measurement of light and illumination
     1. Units of measurement at light sources
     2. Units of measurement on object seen
   - H. Manufactured light sources
     1. Early sources
     2. Modern illuminants
   - I. Lighting problems
     1. Quantity
     2. Diffusion
     3. Brightness differences
   - J. Lighting equipment

BIOLOGY

I. Sight among other forms of life
   - A. Types of eye structure
   - B. Adaptation to environment

II. Light and other forms of life
   - A. Maintaining life for plants
   - B. Light emitted by fireflies, fish, etc.

III. Conditions governing development of human sight

IV. Reaction of human eyes to light

PHYSICS

I. Theories of light
   A. Newton
   B. Huygens
   C. Planck and Einstein

II. Measurement of light
   A. Galileo
   B. Roemer
   C. Michelson
   D. New discoveries

III. Polarization of light

IV. Modern illuminants

CHEMISTRY

I. Relationship between natural and manufactured light

II. Oxidation

III. Modern illuminants
   A. Gas
   B. Electricity
      1. Gaseous discharge lamps
      2. Fluorescence and the fluorescent lamp

HEALTH EDUCATION

(See Topic I, Sight, under General Science, p. 43.)

I. Care of the eyes
   A. First aid
   B. Home treatment of common eye diseases
   C. Medical services

HOME ECONOMICS

I. Home lighting
   A. Control of brightness
   B. Safety
   C. Economy
   D. Decoration

II. Lighting for specialized tasks

III. Lighting equipment
   A. Built-in
   B. Portable

IV. Wiring

V. Maintenance of best lighting conditions

VOCATIONAL GUIDANCE

I. Lighting requirements for various tasks, application to places of employment

II. Training of the visually handicapped

III. Careers in lighting: illuminating engineering, industrial designing

IV. Careers in eye care: ophthalmologist, optometrist, oculist, optician

INDUSTRIAL ARTS

I. Design of portable lamps

II. Wiring and home lighting (hazards, standards, inspection, etc.)

There are also opportunities in other courses for teaching about light and sight. Students in vocational classes where architectural planning is involved should know the principles of lighting and should learn how to indicate electrical requirements in their drawings. A history class can study modes of life and lighting in the past and the principal discoveries and inventions that explain present-day living conditions. Geography, especially economic geography, may deal with sources of power, which are of importance in understanding economic questions. Experiments with colored light and with pigments are as much a part of art as of physics. In English classes, scientific topics can furnish subjects for oral and written presentations. Also, vocabularies of both the "sight" and "light" sections will interest the language-oriented student and can initiate or reinforce an interest in etymology.

There are many possibilities for various classes to work on the same problems of light and sight simultaneously. Such correlation is commendable if the topics can be introduced into the different fields at the places where they naturally belong. When this is not possible, integration of the work on light and sight with the regular work of a department will probably be more effective than artificial attempts at interdepartmental correlation. As suggested earlier, care should be used in attempts at correlation, lest the stu-

dents get bored with a subject because they get too much of it at once.

Methods and Devices

Because classroom teachers are interested in the prevention of vision difficulties, the essence of their work in this area is the recognition and solution of problems that pertain to such difficulties. Hence, they can present much of the work in this area in the form of obvious problems to be solved. Bright sunlight on a page of a book, a dimly lighted page, or the reflection of sunlight from a glass door or mirror are sample starting points for the study of good lighting.

From time to time, pupils' questions can serve as the starting point. Then from these problems and questions, the teacher can guide the classwork toward more subtle situations and to difficulties of which the pupils are not fully aware. When pupils have problems to solve that really interest them or concern their welfare, their work has a genuine motive behind it that tends to maintain their enthusiasm until the study is is finished.

No method of instruction that the teacher has used successfully should be overlooked in the study of light and sight. Teachers should select activities from among the ideas suggested in this publication, according to their suitability to the ages, interests, and abilities of the pupils. Actually, there is less difference between the types of activities suited to elementary-school pupils and those suited to high-school pupils than is sometimes supposed. Various types of work appeal to different pupil interests and prevent any one activity from becoming wearisome. Even though older students can maintain their interest in one type of work for longer periods than young ones can, the wise teacher, in working with any age group, makes a change before the interest lags.

When pupils have a chance to "learn by doing," the process often has special value. Therefore, individual or small-group experiments and activities should have an important place in the work. Well-chosen experiments develop skill in handling laboratory materials and help students to discover their potential as laboratory workers. Experiments also give students a better understanding of the scientific method.

The first lessons on lighting conditions for reading and study may be demonstrations with the pupils acting as subjects. However, whenever the cost or complexity of and experiment makes it impracticable for student work, the teacher may present the situation or problem as a demonstration. In the lower grades, the pupils will talk over what they have seen. Later on, they may write reports on the purpose, method, and results of demonstrations.

Teachers can vary demonstrations by the use of slides, filmstrips, and motion pictures. Before showing them, the teacher should make sure that these audiovisual materials are suitable and that their content is related to the students' present knowledge. The presentation can be followed by discussion and reading. If need be, the audiovisual material can be shown a second or third time, with further discussion and reading. Other visual aids—posters, charts, pictures, structural models of the eye, and working models of lighting equipment and optical instruments—should be available for classroom use.

In addition to experiments and demonstrations, there is a place for straightforward explanations, even in science classes. Pupils cannot "discover" for themselves through their experiments all the facts they need to know. The teacher must explain some things or the students must read about them. Teachers should give brief but accurate replies to the questions of young pupils. Older ones can listen attentively to long explanations, but, generally speaking, formal lectures are not effective at the elementary-school level.

Reading scientific material on light and sight requires special attention to the technical vocabulary. With increased experience and understanding of terminology, students will develop skill in reading and in reporting on their explorations. Many younger pupils will read with appreciation and pleasure the accounts of the lives of inventors and discoverers.

Textbook assignments will have their usual place in the instruction. In addition, the teacher should encourage students to make, at school or at home, such illustrative materials as scrapbooks, original drawings, charts, posters, and models. A few pupils may have the skill and desire to add to the

school's permanent collection of slides by preparing them under the direction of the teacher.

Notebooks with pictures, diagrams, charts, and explanations also help to tell the story of light and sight. Some classes can discuss interesting advertisements and articles about lighting brought to school. Pupils can survey and then report on lighting provisions in their own homes, in new houses in the neighborhood, or in places where they work after school. Such materials can provide a basis for valuable discussions and for suggestions for needed improvements, according to what the class has learned about good lighting. Talented pupils will be able to do experiments at home and give helpful reports on them.

Specific Activities

The experiences described below are arranged according to topic rather than grade level, subject field, or age of pupils. Teachers may prefer to make applications of the exercises different from those suggested. You will note that though much of the source information on which the following activities are based can be found in the text and illustrations in this handbook, some of it is not. The list of references at the back of this manual will provide source material for any missing information. Also useful for student research are simply written encyclopedias.

As for the activities themselves, many suggestions, in addition to those given here, will be found in textbooks, courses of study, and educational journals. The Better Light Better Sight Bureau also publishes teaching materials in the field. (See p. 54 for a list of agencies which supply information and materials.)

POSTURE IN READING AND WRITING

1. Demonstrate, using a pupil subject, the correct way to read at a desk.
2. Demonstrate use of a light meter for checking reading conditions in the classroom. Have the pupils adjust shades and lighting for the highest level of illumination compatible with the most even lighting distribution. (One sees better with even distribution, even when the level of illumination must be lowered somewhat to achieve it.)
3. Find the best location of a lamp for reading at a desk. It should be easy to show that the lamp belongs to one side or slightly to the rear and that the lamp should spread light well. Answer the following questions, using a light meter where necessary:
   a. Is there enough light on the page?
   b. Is the rest of the room adequately lighted?
   c. Are there shadows on the page?
   d. Is the shadow of a pencil held about three inches from the page blurred, showing good diffusion?
   e. Does direct light shine into the reader's eyes?
   f. Is there reflected glare? (If there is, the light source may be seen by the reader in a mirror laid flat on the page.) How can reflected glare be reduced?
4. Demonstrate how to place a lamp to avoid having an annoying shadow of the hand during writing. Give special attention to the left-handed person.
5. Demonstrate placement of a floor or table lamp for typing. It should cast even illumination over the copy, keyboard, and paper.

KINDS OF EYES

1. Observe the location and color of eyes of pet animals and the shapes of their pupils.
2. Observe under a magnifying glass or microscope, or show pictures of, the eyes of the housefly, various insects, snakes, birds, and animals.
3. List the types of eyes observed and discuss the purposes each one serves.

STRUCTURE AND FUNCTION OF THE HUMAN EYE

1. Examine a diagram or model of the eye and learn the names of the different parts. What does each part contribute to seeing?
2. Study a diagram of a cross section of the retina, showing rods and cones. No

one is quite sure exactly how these function. Consult newspaper and science-magazine sources for news of recent studies.

3. Compare the camera and the eye. Which parts of the eye correspond to the parts of the camera? What is the position of the image on the film and retina? Why do we see things right side up?
4. Divide the class into pairs and have each student observe the movement of his partner's eyes as a ruler or pencil is moved from arm's length to within a few inches of the nose.
5. Take one or more children outside into bright sunshine for a few minutes. Bring them back into a dimly lighted vestibule or hall and note how long it is before they can read fine print. One pupil should stay inside while another goes out, and then, using a stop watch, he can time the adaptation period of the one who goes out. Does this explain why people sometimes have difficulty in finding seats at the movies, even when there are plenty of vacant seats?
6. Discuss the changes that take place in the eyes with growth. At what age is binocular vision usually fully developed?

VISION TESTS

1. Give the Snellen test as a demonstration. Why are vision tests given at school called screening tests? Demonstrate, with a clean chart, the importance of proper illumination by giving the test under 1, 10, and 100 footcandles of diffuse illumination. What differences appear in the ability to see as shown by the test? Demonstrate the importance of proper distance and a comfortable position for the person taking the test by having him take it at different distances and when he is uncomfortable.
2. Give the wheel test for astigmatism.
3. Give a test for color blindness. (For information write to the Inter-Society Color Council, P.O. Box 155, Benjamin Franklin Station, Washington, D.C.) Discuss the effect of color blindness on vocational choice.
4. What is the difference between a vision test and an eye examination? Discuss the importance of such tests and examinations whenever there is any question of defective sight.
5. Set up very poor conditions for seeing (dim light, fine print, glare, poor contrast, etc.) and have the pupils tell what happens when they try to see. (Screwing up the face in an effort to see or discomfort when the effort is prolonged.) Important: This experiment should not be unduly prolonged.
6. Have the pupils prepare a list of the signs of visual difficulty for a bulletin board or their notebooks. Can a person always tell whether his difficulty is caused by a defect of sight or by poor lighting? Can a person always tell that he does not see well?
7. Cover one eye and not how limited the range of vision is for one eye working alone. What happens when one tries to thread a needle with one eye covered?

VISUAL DIFFICULTIES AND THEIR CORRECTION

1. How many students have parents and other relatives who wear glasses? What defects are being corrected? How long have they worn glasses?
2. How many members of the class wear glasses? What defects are being corrected? (Take care to avoid embarrassment of any child, particularly the cross-eyed or partially sighted.) Ask for volunteers to demonstrate the difference their glasses make, by showing how close the nearsighted child must come to see the blackboard without his glasses, etc.
3. Report on the history of glasses and arrange an exhibit of the types used.
4. Investigate and report on the services provided by the ophthalmologist, the optometrist, and the optician. Ask a representative of each of these fields to talk to the class.
5. Booklets on vision sometimes contain photographs or drawings showing what people with various uncorrected defects see. Post such a series on the bulletin

board or have a poster made from the pictures.

EYE HEALTH

1. Make a wall chart of rules for eye care, including good lighting.
2. Have the school nurse speak to the class about first aid in case of accidents to the eyes.
3. Make special reports on the control and cure of pinkeye and trachoma.
4. Report on the National Society for the Prevention of Blindness program to control glaucoma by early detection through free examinations. What other blindness-causing diseases can we now arrest? in this country? in other countries?

THE PHYSICS OF LIGHT

1. How was the speed of light estimated? How was it corroborated?
2. Present a diagram of the electromagnetic spectrum showing the place of visible light. What uses are made of the different sections of the electromagnetic spectrum?
3. Report on the contributions of Maxwell and Hertz.

COLOR

1. Place a prism in a narrow beam of sunlight to show the spectrum.
2. Diagram and explain the prism.
3. Use a color disc that can be spun at high speed or primary-color projectors (red, green, and blue) to show the effect of mixing colored light.
4. Place colored filters in a beam of white light to show the effect of subtracting colors from white light.
5. Discuss applications of color mixing in four-color printing and color photography.
6. Place different colored objects in light of different colors to show the effects.
7. Report on the spectrums of incandescent bulbs and fluorescent tubes (manufacturers or dealers can supply the information) and compare them with the spectrum of the sun. Discuss the effects on colors.

REFLECTION

1. Show motes in a beam of sunlight. Why is there light where there is no direct sunlight?
2. With a plane mirror placed on edge on a table and an object reflected in it, have the pupils work out the angles of incidence and reflection of light.
3. Diagram the best positions for light sources for reading, writing, reading music, and other tasks to avoid reflections from the work.
4. Place a mirror and white blotting paper in sunlight. How is the light reflected from each one? Which reflection is more comfortable to look at?
5. Using a light meter, measure the light falling on dull-finished surfaces of different colors. Then, holding the meter two to four inches away from the surface, measure the light reflected. (Be sure no shadow falls on the surface.) How much of the light is reflected? Discuss the colors most desirable for finishing the walls of a classroom, considering the factors of economy in lighting, appearance, eye comfort, and maintenance.

REFRACTION

1. Diagram the change in the direction of light rays from an object seen through a magnifying glass placed at a suitable distance from the object.
2. How does refraction make the microscope and telescope possible?
3. What is a mirage? What other illusions are caused by refraction?
4. Place a black mask with a small hole in it over the beam of a projector. Place a prism in the small beam to show how the light can be reflected by the prism or refracted and dispersed to produce a spectrum.

MEASUREMENT OF LIGHT

1. With a candle, foot rule, and sheet of paper demonstrate roughly what is

meant by the footcandle. Can the footcandle measure be applied to sunlight?

2. Diagram the loss of illumination as a surface is moved away from a point source of light.
3. With a suitable light meter, measure the illumination outside the school building in sunlight, in open shade, and under a tree.
4. Measure the illumination from artificial light sources as it would be at night (windows shaded as much as possible). Make sure the necessary correction factor is applied to the reading for the type of illumination in the room. Sometimes the reading is higher than it should be because of the color composition of the light.
5. Measure the illumination from the windows alone in various parts of the room. Try this on sunny and on cloudy days. Does the room need electric light to give an even distribution of illumination?
6. Give the definition of the footlambert and estimate in footlamberts the brightness of the chalkboard, the wall beside the chalkboard, the page of a book, and a desk top. What is the ratio of brightness between printed page and desk top? Is it too great for comfort?

FLUORESCENT LIGHTING

1. Darken the classroom and place minerals, such as calcite, fluorite, willemite, autunite, and sphalerite in ultraviolet light to show fluorescence.
2. Report on the phosphors used in fluorescent tubes.
3. Demonstrate the effects of different incandescent and fluorescent lamps on colors.

FACTORS IN SEEING

1. Estimate the reflection factors of colored, black, and white paper. Select the combinations that furnish the highest contrast of brightness, disregarding color, and discuss the application to printing.
2. Measure the brightness of various surfaces in the field of vision of a pupil reading at a desk. Discuss how comfortable contrasts can be secured in a study room.
3. Set up a cylindrical Snellen chart on a phonograph turntable that can be operated at different speeds. Without turning the phonograph on, determine the smallest line of type than can be read at 15 feet under dim light. Change to a higher level of illumination and again determine the smallest line of type that can be read at 15 feet. Now turn the phonograph on and with both dim and high illumination determine the smallest line of type that can be read at different speeds. What happens when either the speed of the movement or the amount of illumination is changed?

GLARE

1. Hold a lighted 100-watt bulb directly in the line of vision. Can objects beyond be clearly seen? What difference is made if a 15-watt bulb is used? (Avoid prolonged looking at light.)
2. Look toward a lighted bulb in a diffusing type of fixture. Can objects beyond it be seen? What has happened to the glare from the bulb?
3. Cut a hole two inches in diameter in a sheet of paper—a printed poster will do—and print random letters around the hole. Hold a lighted 100-watt bulb behind the paper about a foot from the hole. Can the random letters be read? Repeat with a 15-watt bulb.
4. Hold a lighted, unshaded bulb in the direct line of vision. Move it to one side until objects in the direct line of vision are clearly seen. How far must it be moved before it ceases entirely to interfere with seeing? Discuss the application to lighting.
5. To discover reflected glare, place a mirror flat on various parts of the printed page. Can an image of the light source be seen by the reader? If so, there is reflected glare. Readjust the light source or the page until the reading matter is well lighted but there is no reflected glare.

6. Why are ordinary sizes of electric bulbs frosted inside?

7. Demonstrate polarizing discs and discuss their use in minimizing glare.

STUDY OF CLASSROOM LIGHTING

1. Record measurements (taken with a light meter) of the level of illumination from natural sources in various parts of the room under different conditions as follows:
   a. Shades up, direct sunlight on desks or walls
   b. Shades up, no direct sunlight entering room
   c. Upper part of windows covered, no direct sunlight
   d. Lower part of windows covered, no direct sunlight
   e. Windows completely shaded
   f. Venetian blinds down, slats adjusted to keep out sunlight.

2. Record measurements (taken with a light meter) of the level of illumination from natural and manufactured light sources as follows:
   a. Shades up, no direct sunlight entering room
   b. Upper part of windows covered, no direct sunlight
   c. Lower part of windows covered, no direct sunlight
   d. Venetian blinds down, slats slanted slightly upward.

3. Record measurements (taken with a light meter) of the level of illumination from natural sources and with only the inner row of fixtures lighted as follows:
   a. Shades up, no direct sunlight entering room
   b. Upper part of windows covered, no direct sunlight
   c. Lower part of windows covered, no direct sunlight
   d. Venetian blinds down, slats slanted slightly upward.

4. Record measurements of manufactured lighting, directly beneath and between lighting units, with shades completely drawn. (With a good installation, the illumination may be so well distributed that the measurements show no significant differences.)

5. Study a list of recommended levels of illumination and of allowable brightness differences within the field of vision and determine under what existing conditions the room is best lighted, i.e., the highest levels consistent with the most even distribution. Can the pupils do their work facing in any direction, or must they turn their seats in some particular direction for easy seeing? Is the lighting under the best existing conditions adequate?

6. Check the room for shiny surfaces that are sources of reflected glare—glass doors, glazed pictures, shiny furniture, chalkboard, etc. Decide whether any could be eliminated, as by sandblasting of glass in doors, or, using a flat varnish, by varnishing pictures (not all can be treated this way) for protection instead of having them glazed. Make out a plan to eliminate reflected glare and discuss having it done with the principal of the school. Also try various combinations of natural and manufactured lighting and shading of windows to overcome reflected glare from surfaces that cannot be changed. Remember to maintain enough illumination and good distribution.

7. Estimate the reflectances of ceiling, walls, floors, and furniture to determine whether they help or hinder the lighting effect. Compare with the recommended reflection factors for schoolrooms. If they are below standard, what would have to be done to improve matters? Would thorough washing be enough? What colors should the walls be painted when redecorating is necessary?

8. If the lighting, position of windows or color of walls, ceiling, and furniture is unsatisfactory in any way, have the pupils make plans for improving matters, with or without rewiring for a different lighting system. They should select suitable paint or window shades. They may need to suggest that pupils turn their desks to avoid glare from the windows. Have experts check the plan.

9. Select committees to survey the auditorium, halls, lunchroom, and other special rooms in the school building and to report on lighting conditions. Develop a check list in class for the committees to follow. Plan necessary changes.
10. Discuss the importance of good lighting and the effects of glare.

STUDY OF HOME LIGHTING

1. Have each pupil report the size, color scheme, and type of lighting fixtures in the room where he studies, in his bedroom, in the whole house. Discuss whether arrangements found give proper lighting effects. Compare the rooms described with recommended practices for home lighting. Discuss how to make the best use of existing equipment. Discuss inexpensive plans for improvement. The teacher should use care to keep pupils from antagonizing their parents by any implied criticism.
2. Examine or have reports made on direct, semidirect, indirect, and semi-indirect portable lamps. Discuss the features of good lamps for reading, writing, sewing, and use on the dressing table. Why are diffusing bowls desirable except on the dressing table? Why should only good quality bowls be used?
3. Have the pupils make a drawing of the plan of a room, showing the decoration and the placement of furniture and lighting units for good lighting effects. The plan should be one that could be put into effect at moderate cost.
4. Select a committee of pupils to report on the lighting of new houses or of one or more houses recently remodeled. Make a check list of what to look for.
5. Plan ideal lighting for a kitchen, laundry room, dining room, bedroom.
6. Plan shades or drapes for different types and sizes of windows, taking into account both good lighting and artistic effect.
7. Plan the lighting for a workbench in the home.
8. Plan inexpensive ways of improving lamp shades and home lighting.

The suggestions given above are activities that should help to give pupils a practical understanding of good lighting and of its importance and how to achieve it. Pupils should also learn about community agencies that are interested in conserving sight and preventing blindness. They should investigate government standards for the lighting and equipment of industries and other buildings, the laws and regulations governing lighting for schools, and the standards followed for street lighting. They should find out what is done in the community to prevent the spread of diseases affecting the eyes. In summary, pupils should leave school with an understanding of how lighting affects their own efficiency and comfort and with some experience in planning good lighting arrangements.

SOURCES OF INFORMATION

Books and Pamphlets

ADLER, FRANCIS H. *Gifford's Textbook of Ophthalmology.* Fifth edition. Philadelphia: W. B. Saunders Co., 1953. 488 pp.

ALLPHIN, WILLARD. *Primer of Lamps and Lighting.* Philadelphia: Chilton Co., 1959. 241 pp. $10.

AMERICAN ASSOCIATION OF SCHOOL ADMINISTRATORS. *Planning America's School Buildings.* Washington, D.C.: the Association, a department of the National Education Association, 1960. 229 pp. $6.

AMERICAN OPTOMETRIC ASSOCIATION. *Your Eyes and Their Examination.* Publication G-7. St. Louis: the Association, 1960. 8 pp. 4¢.

CARMICHAEL, LEONARD, AND DEARBORN, WALTER F. *Reading and Visual Fatigue.* Boston: Houghton Mifflin Co., 1947. 483 pp. $5.50.

COMMERY, E. W., AND STEPHENSON, C. EUGENE. *How To Decorate and Light Your Home.* New York: Coward-McCann, 1955. 256 pp. $6.75.

COWAN, ALFRED. *Refraction of the Eye.* Third edition. Philadelphia: Lea and Febiger, 1948. 287 pp.

HATHAWAY, WINIFRED. *Education and Health of the Partially Seeing Child.* Third edition. New York: Columbia University Press, 1954. 227 pp.

ILLUMINATING ENGINEERING SOCIETY. *IES Lighting Fundamentals Course.* New York: the Society, 1961. 104 pp. $3.

ILLUMINATING ENGINEERING SOCIETY. *IES Lighting Handbook.* Third edition. New York: the Society, 1959. 1109 pp.

ILLUMINATING ENGINEERING SOCIETY. *Laboratory Activities with Light.* (ED-1). New York: the Society, 1959. 42 pp. $1.

ILLUMINATING ENGINEERING SOCIETY. *Lighting Keyed to Today's Homes.* (CP-14). New York: the Society, 1960. 86 pp. $1.50.

ILLUMINATING ENGINEERING SOCIETY. *School Lighting Application Data.* New York: the Society, 1962. 20 pp. 20¢.

ILLUMINATING ENGINEERING SOCIETY, AMERICAN INSTITUTE OF ARCHITECTS, AND THE NATIONAL COUNCIL ON SCHOOLHOUSE CONSTRUCTION. *American Standard Guide for School Lighting.* (ASA-A-23). New York: the Society, 1962. 40 pp. 50¢.

ILLUMINATING ENGINEERING SOCIETY, RESIDENCE LIGHTING COMMITTEE. *Recommended Practice for Residential Lighting.* New York: the Society, 1953. 44 pp. $1.

LEWIS, FLOYD A. *The Incandescent Light.* New York: Shorewood Publishers, 1961. 128 pp. $2.95.

MOON, PARRY. *Scientific Basis of Illuminating Engineering.* New York: McGraw-Hill Book Co., 1936. 608 pp.

NATIONAL COUNCIL ON SCHOOLHOUSE CONSTRUCTION. *Guide for Planning School Plants.* 1958 edition. East Lansing, Mich.: the Council, 1958. 254 pp. $3.

NATIONAL EDUCATION ASSOCIATION AND AMERICAN MEDICAL ASSOCIATION, JOINT COMMITTEE ON HEALTH PROBLEMS IN EDUCATION. *Health Education.* Fifth edition. Washington, D.C.: National Education Association, 1961. 429 pp. $5.

NATIONAL EDUCATION ASSOCIATION AND AMERICAN MEDICAL ASSOCIATION, JOINT COMMITTEE ON HEALTH PROBLEMS IN EDUCATION. *Healthful School Living.* Washington, D.C.: National Education Association, 1957. 323 pp. $5.

NATIONAL EDUCATION ASSOCIATION AND AMERICAN MEDICAL ASSOCIATION, JOINT COMMITTEE ON HEALTH PROBLEMS IN EDUCATION. *School Health Services.* Washington, D.C.: National Education Association, 1953. 486 pp. $5.

NATIONAL EDUCATION ASSOCIATION, DEPARTMENT OF AUDIO-VISUAL INSTRUCTION. *Plan-*

ning Schools for Use of Audio-Visual Materials: No. 1, Classrooms. Washington, D.C.: the Department, 1958. 64 pp. $1.50.

NATIONAL EDUCATION ASSOCIATION, DEPARTMENT OF ELEMENTARY SCHOOL PRINCIPALS. *Elementary School Buildings—Design for Learning.* Thirty-Seventh Yearbook. Washington, D.C.: the Department, 1959. 200 pp. $4.

NATIONAL MEDICAL FOUNDATION FOR EYE CARE. *Eye Cues for Eye Care for Children.* New York: the Foundation, 1961. 6 pp. $1.25 per 100. Single copy free to teachers upon request to the Foundation.

NATIONAL MEDICAL FOUNDATION FOR EYE CARE. *Identification of School Children Requiring Eye Care.* New York: the Foundation, 1959. 36 pp. 25¢. Single copy free to teachers upon request to the Foundation.

NATIONAL SOCIETY FOR THE PREVENTION OF BLINDNESS. *Signs of Eye Trouble in Children.* Publication No. G102. New York: the Society, 1962. $1.75 per 100. Single copy free upon request to the Society.

NATIONAL SOCIETY FOR THE PREVENTION OF BLINDNESS. *Snellen Chart.* Publication No. V3. New York: the Society. 35¢. (Double-faced, cardboard.)

NATIONAL SOCIETY FOR THE PREVENTION OF BLINDNESS. *Vocabulary of Terms Relating to the Eye.* Publication No. P607. New York: the Society, 1962. 8 pp. 10¢.

PERERA, CHARLES A. *May's Manual of the Diseases of the Eye.* Twenty-first edition. Baltimore: Williams and Wilkins Co., 1953. 512 pp.

RUECHARDT, EDUARD. *Light, Visible and Invisible.* Ann Arbor: University of Michigan Press, 1958. 201 pp. $1.95.

SEAGERS, PAUL W. *Light, Vision and Learning.* New York: Better Light Better Sight Bureau, 1962. 96 pp. $1.

STALEY, KARL A. *Fundamentals of Light and Lighting.* Bulletin LD-2. Cleveland, Ohio: General Electric Co., 1960. 96 pp.

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, OFFICE OF EDUCATION. *Environmental Engineering for the School.* Publication OE 21014. Washington, D.C.: Government Printing Office, 1961. 74 pp. 50¢.

WESTINGHOUSE ELECTRIC CORPORATION, LAMP DIVISION. *Westinghouse Lighting Handbook.* Bloomfield, N.J.: the Corporation, 1956. 100 pp.

WESTON, H. C. *Sight, Light and Efficiency.* London: H. K. Lewis and Co., 1949. 308 pp.

WOLFF, EUGENE. *Anatomy of the Eye and Orbit.* Fourth edition. London: H. K. Lewis and Co., 1954. 491 pp.

Selected List of Periodicals

Many periodicals in the fields of education, child care, hygiene, home economics, lighting, and personnel work publish articles from time to time that deal with lighting and eye welfare. The inclusion or omission of any periodical is not to be construed as implying approval or disapproval by the National Education Association.

American Journal of Ophthalmology

664 N. Michigan Ave., Chicago 11, Ill. 12 issues a year. Subscription $12. Ophthalmology. Includes studies of light and illumination in relation to the eyes.

American Journal of Optometry

1502 Foshay Tower, Minneapolis, Minn. 12 issues a year. Subscription $6. Optometry.

Archives of Ophthalmology

American Medical Association, 535 N. Dearborn St., Chicago 10, Ill. 12 issues a year. Subscription $12. Diseases of the eyes. Includes studies of light and illumination in relation to the eyes.

Better Light Better Sight News

Better Light Better Sight Bureau, 750 3rd Ave., New York 17, N.Y. 6 issues a year. Subscription $1.50. Contains articles on the relation of light to sight and on lighting for various visual tasks.

Illuminating Engineering

Illuminating Engineering Society, 345 E. 47th St., New York, N.Y. 12 issues a year. Subscription $18. Science of lighting.

Journal of the American Optometric Association

American Optometric Association, 4030 Chouteau Ave., St. Louis 10, Mo. 12 issues a year. Subscription $7.50. Optometry.

Light Magazine

General Electric Company, Large Lamp Department, Nela Park, Cleveland, Ohio. 4 issues a year. Distribution through G.E. Lamp Division Sales District Offices.

Lighting

1760 Peachtree Rd., N.W., Atlanta 9, Ga. 12 issues a year. Subscription $3. Lighting.

Optical Journal and Review of Optometry

The Chilton Company, 56th and Chestnut Sts., Philadelphia 39, Pa. 24 issues a year. Subscription $3.

Public Health Reports

Government Printing Office, Washington 25, D.C. 12 issues a year. Subscription $4.25. Articles on all phases of public health.

Science Digest

200 E. Ontario St., Chicago 11, Ill. 12 issues a year. Subscription $3. General science. Includes articles on the care of the eyes.

Sight-Saving Review

National Society for the Prevention of Blindness, 16 E. 40th St., New York 16, N.Y. 4 issues a year. Subscription $3.50. Articles on the causes and prevention of blindness and impaired vision, education for eye health, lighting, etc.

Today's Health

American Medical Association, 535 N. Dearborn St., Chicago 10, Ill. 12 issues a year. Subscription $2.50. Available in many libraries. Articles on various aspects of health, including the care of the eyes.

Agencies Supplying Information and Materials

Many agencies provide information and materials on eye health and lighting. Local and state agencies which supply information and materials to teachers include colleges of agriculture, departments of health, departments of education, state university extension services, and public utility companies. The inclusion or omission of any agency is not to be construed as implying approval or disapproval by the National Education Association.

Governmental Agencies

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, CHILDREN'S BUREAU, 330 Independence Ave., S.W., Washington 25, D.C. Publishes materials on various aspects of child care and development, including health.

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, OFFICE OF EDUCATION, 330 Independence Ave., S.W., Washington 25, D.C. Includes among its publications various studies on school health education.

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, PUBLIC HEALTH SERVICE, 330 Independence Ave., S.W., Washington 25, D.C. All aspects of public health problems treated in its publications.

Other Agencies

AMERICAN MEDICAL ASSOCIATION, 535 N. Dearborn St., Chicago 10, Ill. Send for list of publications on health education. Its publications include materials for both physicians and laymen.

AMERICAN OPTOMETRIC ASSOCIATION, 4030 Chouteau Ave., St. Louis 10, Mo. Send for list of publications.

BETTER LIGHT BETTER SIGHT BUREAU, 750 3rd Ave., New York 17, N.Y. Source of information on the application of light to visual tasks to promote easy seeing. Also publishes teaching materials on lighting.

BETTER VISION INSTITUTE, 230 Park Ave., New York 17, N.Y. Send for list of publications.

EDISON ELECTRIC INSTITUTE, 750 3rd Ave., New York 17, N.Y. Send for list of publications.

GENERAL ELECTRIC COMPANY, LAMP DIVISION, Nela Park, Cleveland 12, Ohio. Source of information on developments in lighting

and their application to visual tasks in the home, in school, and in places of employment.

INTERNATIONAL COMMISSION ON ILLUMINATION, 57 Rue Cuvier, Paris 5, France. International standards on illumination.

JOHN HANCOCK MUTUAL LIFE INSURANCE COMPANY, LIFE CONSERVATION SERVICE, Boston, Mass. Has material covering many aspects of health protection and promotion.

METROPOLITAN LIFE INSURANCE COMPANY, 1 Madison Ave., New York 10, N.Y. Maintains a School Health Bureau and has material relating to many phases of health education. Send for list of publications.

NATIONAL EDUCATION ASSOCIATION, 1201 16th St., N.W., Washington 6, D.C. Send for special folder listing health education publications.

NATIONAL MEDICAL FOUNDATION FOR EYE CARE, 250 W. 57th St., New York 19, N.Y. Source of information to teachers, physicians, nurses, and others regarding the eye health of both children and adults. Publishes numerous pamphlets on the eyes and their care.

NATIONAL SOCIETY FOR THE PREVENTION OF BLINDNESS, 16 E. 40th St., New York 16, N.Y. Source of assistance to teachers in the promotion of eye health in the school program. Publishes numerous pamphlets on the eyes and their care.

SYLVANIA LIGHTING PRODUCTS, 1740 Broadway, New York 19, N.Y. Source of information on developments in lighting and their application to visual tasks in the home, in school, and in places of employment.

THOMAS ALVA EDISON FOUNDATION, 8 W. 40th St., New York 18, N.Y. Source of information on Edison and his inventions. Sponsor of National Science Youth Week. Write for list of publications.

WESTINGHOUSE ELECTRIC CORPORATION, LAMP DIVISION, Bloomfield, N.J. Source of information on developments in lighting and their application to visual tasks in the home, in school, and in places of employment.